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Our cover The radio telescope dish at Parkes Observatory, in south-east Australia, is run by the Australian Telescope National Facility, a division of the Commonwealth Scientific and Industrial Research Organization. The dish is 64 m in diameter and is used for tracking space probes.

You may have seen photographs of other radio telescope dishes such as this. What kinds of telescopes were used to investigate space before radio telescopes? How much more powerful are radio telescopes than the ones that were previously used? Find out what you can in answer to these questions as you read Unit 5 in this textbook. Do some library or Internet research to add to your knowledge.

SCIENCEFOCUS 9

Science • Technology • Society

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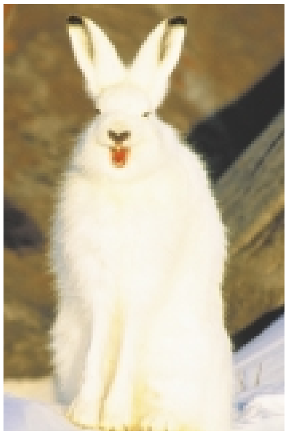

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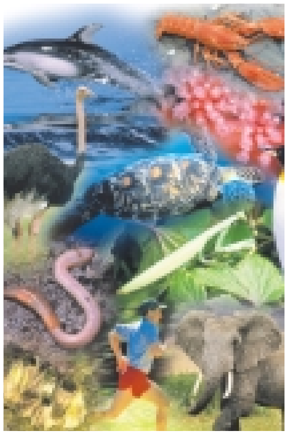

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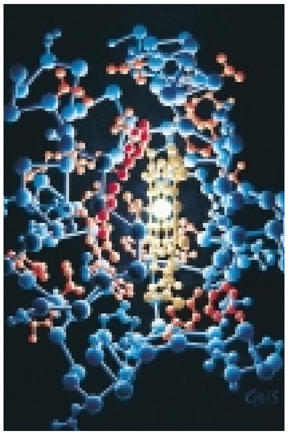

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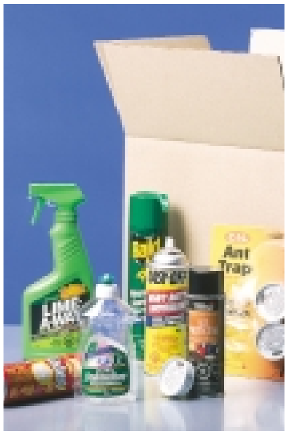

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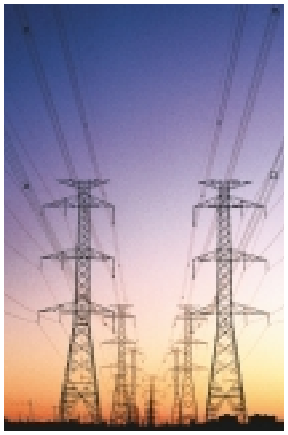

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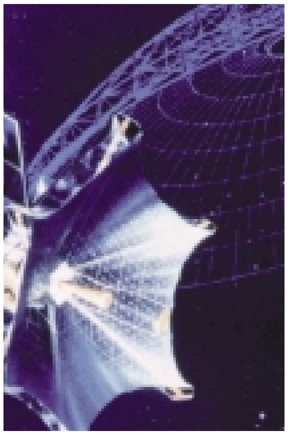

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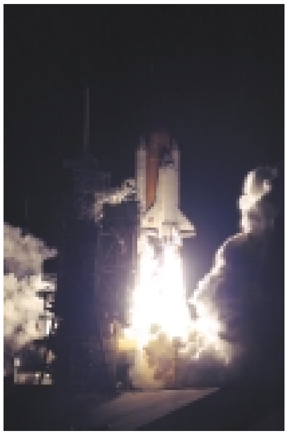

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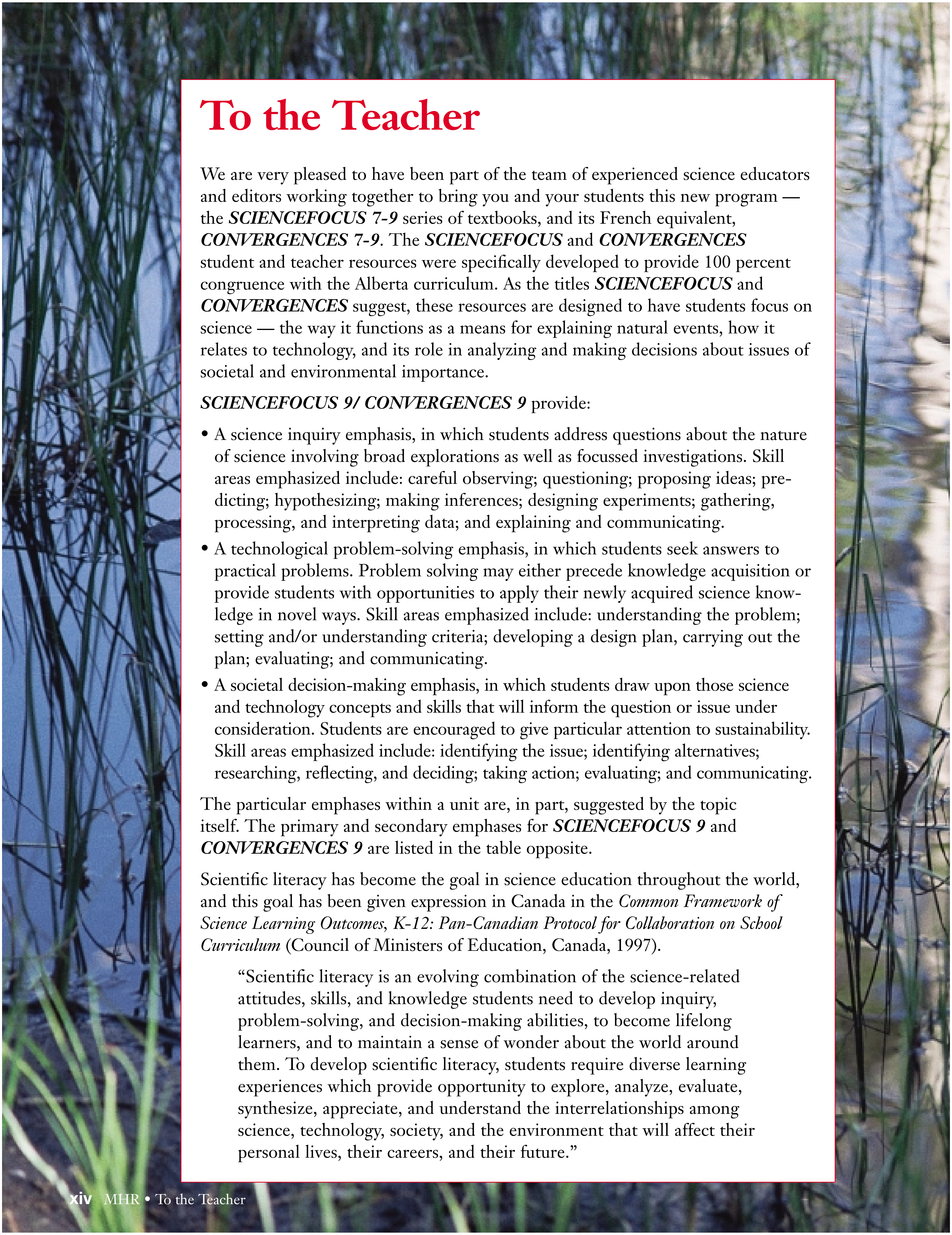


To the Teacher

We are very pleased to have been part of the team of experienced science educators and editors working together to bring you and your students this new program — the ***SCIENCEFOCUS* 7-9** series of textbooks, and its French equivalent, ***CONVERGENCES* 7-9**. The ***SCIENCEFOCUS*** and ***CONVERGENCES*** student and teacher resources were specifically developed to provide 100 percent congruence with the Alberta curriculum. As the titles ***SCIENCEFOCUS*** and ***CONVERGENCES*** suggest, these resources are designed to have students focus on science — the way it functions as a means for explaining natural events, how it relates to technology, and its role in analyzing and making decisions about issues of societal and environmental importance.

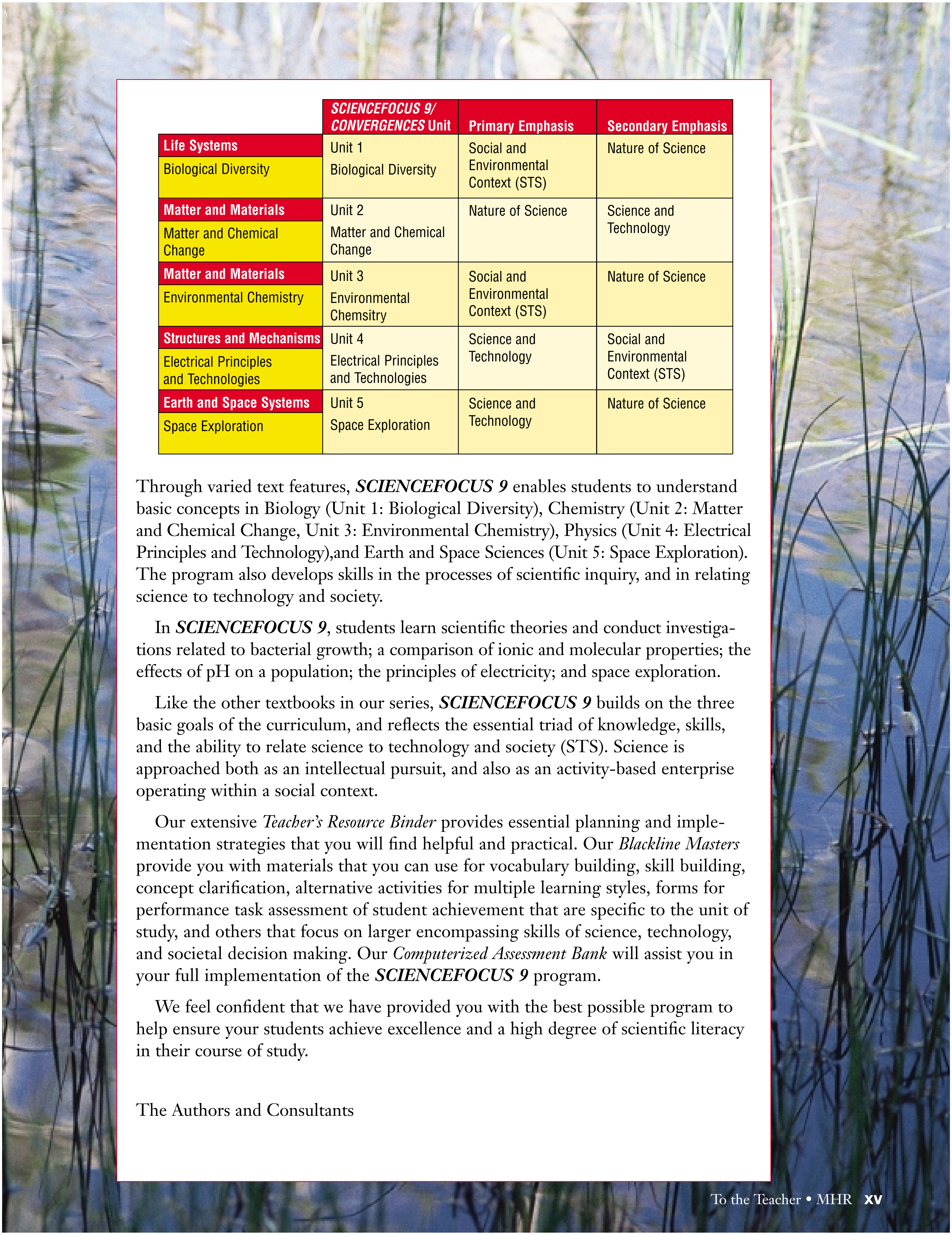
SCIENCEFOCUS 9/ CONVERGENCES 9 provide:

- A science inquiry emphasis, in which students address questions about the nature of science involving broad explorations as well as focussed investigations. Skill areas emphasized include: careful observing; questioning; proposing ideas; predicting; hypothesizing; making inferences; designing experiments; gathering, processing, and interpreting data; and explaining and communicating.
- A technological problem-solving emphasis, in which students seek answers to practical problems. Problem solving may either precede knowledge acquisition or provide students with opportunities to apply their newly acquired science knowledge in novel ways. Skill areas emphasized include: understanding the problem; setting and/or understanding criteria; developing a design plan, carrying out the plan; evaluating; and communicating.
- A societal decision-making emphasis, in which students draw upon those science and technology concepts and skills that will inform the question or issue under consideration. Students are encouraged to give particular attention to sustainability. Skill areas emphasized include: identifying the issue; identifying alternatives; researching, reflecting, and deciding; taking action; evaluating; and communicating.

The particular emphases within a unit are, in part, suggested by the topic itself. The primary and secondary emphases for ***SCIENCEFOCUS 9*** and ***CONVERGENCES 9*** are listed in the table opposite.

Scientific literacy has become the goal in science education throughout the world, and this goal has been given expression in Canada in the *Common Framework of Science Learning Outcomes, K-12: Pan-Canadian Protocol for Collaboration on School Curriculum* (Council of Ministers of Education, Canada, 1997).

> "Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them. To develop scientific literacy, students require diverse learning experiences which provide opportunity to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, their careers, and their future."



	SCIENCEFOCUS 9/ CONVERGENCES **Unit**	**Primary Emphasis**	**Secondary Emphasis**
Life Systems Biological Diversity	Unit 1 Biological Diversity	Social and Environmental Context (STS)	Nature of Science
Matter and Materials Matter and Chemical Change	Unit 2 Matter and Chemical Change	Nature of Science	Science and Technology
Matter and Materials Environmental Chemistry	Unit 3 Environmental Chemsitry	Social and Environmental Context (STS)	Nature of Science
Structures and Mechanisms Electrical Principles and Technologies	Unit 4 Electrical Principles and Technologies	Science and Technology	Social and Environmental Context (STS)
Earth and Space Systems Space Exploration	Unit 5 Space Exploration	Science and Technology	Nature of Science

Through varied text features, ***SCIENCEFOCUS 9*** enables students to understand basic concepts in Biology (Unit 1: Biological Diversity), Chemistry (Unit 2: Matter and Chemical Change, Unit 3: Environmental Chemistry), Physics (Unit 4: Electrical Principles and Technology),and Earth and Space Sciences (Unit 5: Space Exploration). The program also develops skills in the processes of scientific inquiry, and in relating science to technology and society.

In ***SCIENCEFOCUS 9***, students learn scientific theories and conduct investigations related to bacterial growth; a comparison of ionic and molecular properties; the effects of pH on a population; the principles of electricity; and space exploration.

Like the other textbooks in our series, ***SCIENCEFOCUS 9*** builds on the three basic goals of the curriculum, and reflects the essential triad of knowledge, skills, and the ability to relate science to technology and society (STS). Science is approached both as an intellectual pursuit, and also as an activity-based enterprise operating within a social context.

Our extensive *Teacher's Resource Binder* provides essential planning and implementation strategies that you will find helpful and practical. Our *Blackline Masters* provide you with materials that you can use for vocabulary building, skill building, concept clarification, alternative activities for multiple learning styles, forms for performance task assessment of student achievement that are specific to the unit of study, and others that focus on larger encompassing skills of science, technology, and societal decision making. Our *Computerized Assessment Bank* will assist you in your full implementation of the ***SCIENCEFOCUS 9*** program.

We feel confident that we have provided you with the best possible program to help ensure your students achieve excellence and a high degree of scientific literacy in their course of study.

The Authors and Consultants

Focus on

Key Concepts	Unit 1	Unit 2	
	In this unit, you will investigate ▪ the role of variation in helping organisms to survive changing environmental conditions ▪ advantages and disadvantages of sexual and asexual reproduction in the transmission of characteristics from parents to offspring ▪ how genetic information is stored by the body's cells and molecules ▪ how people increase variation in other organisms ▪ strategies for minimizing the impacts of human action on the survival of organisms	In this unit, you will investigate ▪ the importance of safe procedures when you are working with chemicals ▪ differences between physical and chemical changes ▪ ideas used in interpreting evidence of the chemical nature of matter ▪ the development and use of the periodic table ▪ the composition and interpretation of chemical forumalas ▪ patterns in chemical reactions and reaction rate	
Key Skills			
	In this unit, you will ▪ observe interactions of organisms in soil communities ▪ observe and analyze a variety of human characteristics ▪ design an investigation to identify the circumstances under which bread mould will grow ▪ research and analyze a scientific issue on your own and as part of a group; then develop solutions to the ethical problem it raises ▪ analyze data relating to genetics and the environment and their influence on human variation	In this unit, you will ▪ identify and work with WHMIS symbols ▪ conduct an investigation to test the Law of Conservation of Mass ▪ use a chemical reaction to recover solute from a solution ▪ identify elements, using the periodic table ▪ identify ionic and non-ionic substances and compare their properties ▪ design an investigation to find out whether an endothermic or an exothermic reaction is produced when hydrogen peroxide is combined with certain substances	
Key Attitudes			
	In this unit, you will be encouraged to ▪ recognize that science can help us to assess our impact on the environment, but it cannot accurately predict future impacts ▪ carefully analyze data in order to assess problems accurately and work toward effective decisions ▪ appreciate the effects of changing the environment on living organisms ▪ consider the needs of other organisms when attempting to meet human needs	In this unit, you will be encouraged to ▪ appreciate that scientists use models which are not always verifiable to further their research ▪ follow appropriate procedures in obtaining and reporting accurate and complete data ▪ ensure your own understanding and that of others in your class of safety symbols and their use ▪ ensure that chemicals used in investigations are disposed of appropriately	

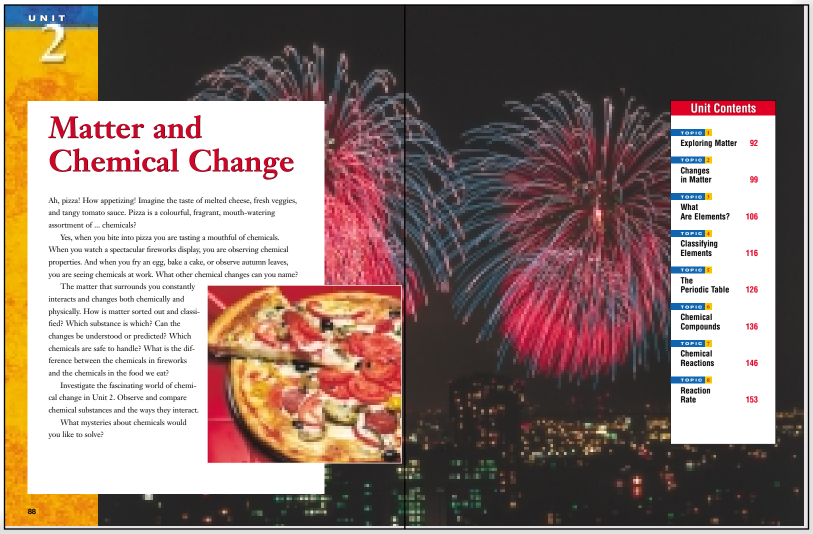
	Unit 3	Unit 4	Unit 5
	In this unit, you will investigate ■ the role of chemicals in maintaining the health of an organism and supplying its nutrients ■ the positive and sometimes unforeseen negative effects of chemicals in the environment ■ the acidity of common substances and the effect of its variation on organisms ■ methods of detecting the presence of chemicals in the environment and assessing any risks they pose ■ the presence of chemicals in water ■ methods of waste management	In this unit, you will investigate ■ electric charge and its movement in circuits ■ electric current, voltage, and resistance ■ differences between series and parallel circuits ■ energy transformations in electric circuits ■ construction and features of different types of electrochemical cells and batteries ■ the operation of generators and motors ■ environmental impacts of different ways of generating electricity	In this unit, you will investigate ■ different perspectives on the nature of Earth and space ■ the technology of space exploration: optical and radio telescopes, spectral analysis, and space travel ■ techniques for determining the position and motion of objects in space ■ technologies used in global positioning systems and in remote sensing ■ life-support technologies used in space ■ materials and processes developed for use in space and risks associated with space exploration
	In this unit, you will ■ test the reaction of a plant to the addition of certain chemicals ■ trace the path of a harmful chemical through the food chain ■ conduct tests to find the pH of a number of common substances ■ observe the effects of variations in pH on the growth of yeast ■ test the effectiveness of bases in neutralizing an acid ■ use macroinvertebrates to test water quality ■ conduct a survey of household hazardous wastes	In this unit, you will ■ construct a simple circuit and use an ammeter and voltmeter to find current and voltage at different points ■ examine the relationship between the current in a circuit, the voltage across the load, and the resistance of the load ■ design and construct an electrical circuit with specific characteristics ■ construct electrochemical cells and batteries ■ construct a working electric motor ■ calculate the efficiency of an electrical device	In this unit, you will ■ build a device to measure altitude-azimuth co-ordinates and organize data using a format that is appropriate to the task ■ identify and correct practical problems in the function of a simple telescope you have constructed ■ examine light sources using a spectroscope and predict the kind of spectra you will see ■ select and integrate information from print and electronic sources on the planets in the solar system ■ test the design of a remote manipulation device you have constructed
	In this unit, you will be encouraged to ■ appreciate that many valid viewpoints must be heard when decisions about environmental quality need to be made ■ carefully collect and analyze evidence when assessing a problem or situation ■ develop your awareness of the environmental consequences of disposing of the items that contribute to our lifestyle	In this unit, you will be encouraged to ■ continue to work on problems or designs until you find the best solution ■ take a responsible part in problem solving and trouble shooting in any group activity you undertake ■ demonstrate awareness of the need to balance human needs and wants with sustaining the environment ■ practise safe procedures when working with electricity	In this unit, you will be encouraged to ■ show concern for safety in planning, carrying out, and reviewing activities ■ appreciate the role, contributions, and limits of science and technology in space exploration ■ work collaboratively in carrying out investigations related to space exploration ■ appreciate the diversity of people and cultures that have contributed to our understanding of space

A Tour of Your Textbook

Welcome to *SCIENCEFOCUS 9*. This textbook introduces you to the wonders of biodiversity; the amazing world of chemicals and their positive and negative effects on the environment; the "magic" of electricity; and exploration into the far reaches of space To understand the book's structure, begin by taking the brief tour on the following pages. Then do the *Feature Hunt* on page xxv to check your understanding of how to use this book.

Unit Opener

- ***SCIENCEFOCUS 9*** has five major units.
- Each unit opener provides a clear overview of the unit's contents.
- The unit opener sparks interest in the subject by suggesting a technological challenge to think about, presenting science ideas to investigate, or highlighting a societal issue to explore.
- The unit opener identifies each of the unit's Topics.



UNIT 2

Matter and Chemical Change

Ah, pizza! How appetizing! Imagine the taste of melted cheese, fresh veggies, and tangy tomato sauce. Pizza is a colourful, fragrant, mouth-watering assortment of ... chemicals?

Yes, when you bite into pizza you are tasting a mouthful of chemicals. When you watch a spectacular fireworks display, you are observing chemical properties. And when you fry an egg, bake a cake, or observe autumn leaves, you are seeing chemicals at work. What other chemical changes can you name?

The matter that surrounds you constantly interacts and changes both chemically and physically. How is matter sorted out and classified? Which substance is which? Can the changes be understood or predicted? Which chemicals are safe to handle? What is the difference between the chemicals in fireworks and the chemicals in the food we eat?

Investigate the fascinating world of chemical change in Unit 2. Observe and compare chemical substances and the ways they interact.

What mysteries about chemicals would you like to solve?

88

Unit Contents

TOPIC 1 Exploring Matter 92

TOPIC 2 Changes in Matter 99

TOPIC 3 What Are Elements? 106

TOPIC 4 Classifying Elements 116

TOPIC 5 The Periodic Table 126

TOPIC 6 Chemical Compounds 136

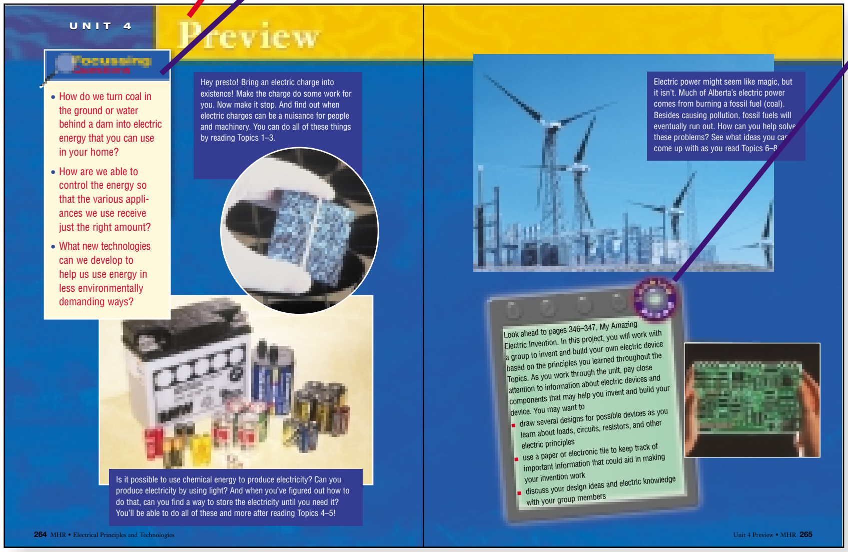
TOPIC 7 Chemical Reactions 146

TOPIC 8 Reaction Rate 153

Unit Preview

Each unit preview draws you into the major emphasis of the unit: science inquiry, technological problem solving, or societal decision making.

- **Focussing questions** invite you to reflect on what you already know (or will learn) about the upcoming Topics.
- Interesting photographs are combined with brief descriptions of what you will find in each cluster of Topics.



UNIT 4

Preview

Focussing Questions

- How do we turn coal in the ground or water behind a dam into electric energy that you can use in your home?
- How are we able to control the energy so that the various appliances we use receive just the right amount?
- What new technologies can we develop to help us use energy in less environmentally demanding ways?

Hey presto! Bring an electric charge into existence! Make the charge do some work for you. Now make it stop. And find out when electric charges can be a nuisance for people and machinery. You can do all of these things by reading Topics 1–3.

Is it possible to use chemical energy to produce electricity? Can you produce electricity by using light? And when you've figured out how to do that, can you find a way to store the electricity until you need it? You'll be able to do all of these and more after reading Topics 4–5!

264 MHR • Electrical Principles and Technologies

Electric power might seem like magic, but it isn't. Much of Alberta's electric power comes from burning a fossil fuel (coal). Besides causing pollution, fossil fuels will eventually run out. How can you help solve these problems? See what ideas you can come up with as you read Topics 6–8

Look ahead to pages 346–347, My Amazing Electric Invention. In this project, you will work with a group to invent and build your own electric device based on the principles you learned throughout the Topics. As you work through the unit, pay close attention to information about electric devices and components that may help you invent and build your device. You may want to

- draw several designs for possible devices as you learn about loads, circuits, resistors, and other electric principles
- use a paper or electronic file to keep track of important information that could aid in making your invention work
- discuss your design ideas and electric knowledge with your group members

Unit 4 Preview • MHR 265

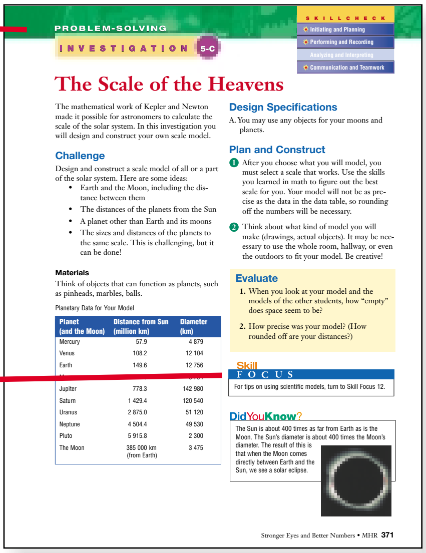
- **Looking Ahead** helps you to prepare for your end-of-unit challenge. It gives you an idea of what you will be doing and provides suggestions to get you started on this group task. This feature is always presented in a Palm Pilot™ frame to remind you to make the best use of the current technology that is available to you.

Problem-Solving Investigation

- These hands-on activities set challenges to design and construct your own models, systems, or products. They teach design skills and blend science and technology in new and different ways.
- The co-operative group work icon signals that you will be doing these investigations in a team.
- The Design Specifications provide a way to evaluate your results.
- You and your team members are then on your own to design and construct!

Skill Focus

- Skill development tips refer you to the **Science Skills Guide** at the back of the student text. (The Contents page of the **Science Skills Guide** is shown on page xxv, "Wrapping Up the Tour.")
- These tips provide specific skill development strategies and activities as they are needed, for example, in using problem-solving processes and in using scientific models.



PROBLEM-SOLVING
INVESTIGATION 5-C

SKILLCHECK
Initiating and Planning
Performing and Recording
Analyzing and Interpreting
Communication and Teamwork

The Scale of the Heavens

The mathematical work of Kepler and Newton made it possible for astronomers to calculate the scale of the solar system. In this investigation you will design and construct your own scale model.

Challenge

Design and construct a scale model of all or a part of the solar system. Here are some ideas:

- Earth and the Moon, including the distance between them
- The distances of the planets from the Sun
- A planet other than Earth and its moons
- The sizes and distances of the planets to the same scale. This is challenging, but it can be done!

Materials

Think of objects that can function as planets, such as pinheads, marbles, balls.

Planetary Data for Your Model

Planet (and the Moon)	Distance from Sun (million km)	Diameter (km)
Mercury	57.9	4 879
Venus	108.2	12 104
Earth	149.6	12 756
[illegible]	[illegible]	[illegible]
Jupiter	778.3	142 980
Saturn	1 429.4	120 540
Uranus	2 875.0	51 120
Neptune	4 504.4	49 530
Pluto	5 915.8	2 300
The Moon	385 000 km (from Earth)	3 475

Design Specifications

A. You may use any objects for your moons and planets.

Plan and Construct

① After you choose what you will model, you must select a scale that works. Use the skills you learned in math to figure out the best scale for you. Your model will not be as precise as the data in the data table, so rounding off the numbers will be necessary.

② Think about what kind of model you will make (drawings, actual objects). It may be necessary to use the whole room, hallway, or even the outdoors to fit your model. Be creative!

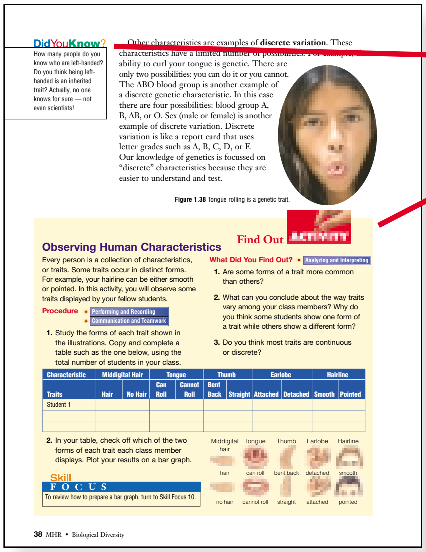
Evaluate

1. When you look at your model and the models of the other students, how "empty" does space seem to be?
2. How precise was your model? (How rounded off are your distances?)

Skill FOCUS
For tips on using scientific models, turn to Skill Focus 12.

DidYouKnow?
The Sun is about 400 times as far from Earth as is the Moon. The Sun's diameter is about 400 times the Moon's diameter. The result of this is that when the Moon comes directly between Earth and the Sun, we see a solar eclipse.

Stronger Eyes and Better Numbers • MHR 371



DidYouKnow?
How many people do you know who are left-handed? Do you think being left-handed is an inherited trait? Actually, no one knows for sure — not even scientists!

Other characteristics are examples of **discrete variation**. These characteristics have a limited number of possibilities. For example, the ability to curl your tongue is genetic. There are only two possibilities: you can do it or you cannot. The ABO blood group is another example of a discrete genetic characteristic. In this case there are four possibilities: blood group A, B, AB, or O. Sex (male or female) is another example of discrete variation. Discrete variation is like a report card that uses letter grades such as A, B, C, D, or F. Our knowledge of genetics is focussed on "discrete" characteristics because they are easier to understand and test.

Figure 1.38 Tongue rolling is a genetic trait.

Find Out ACTIVITY

Observing Human Characteristics

Every person is a collection of characteristics, or traits. Some traits occur in distinct forms. For example, your hairline can be either smooth or pointed. In this activity, you will observe some traits displayed by your fellow students.

Procedure Performing and Recording; Communication and Teamwork

1. Study the forms of each trait shown in the illustrations. Copy and complete a table such as the one below, using the total number of students in your class.

Characteristic	Middigital Hair		Tongue		Thumb		Earlobe		Hairline	
Traits	Hair	No Hair	Can Roll	Cannot Roll	Bent Back	Straight	Attached	Detached	Smooth	Pointed
Student 1										

2. In your table, check off which of the two forms of each trait each class member displays. Plot your results on a bar graph.

Middigital hair: hair, no hair
Tongue: can roll, cannot roll
Thumb: bent back, straight
Earlobe: detached, attached
Hairline: smooth, pointed

Skill FOCUS
To review how to prepare a bar graph, turn to Skill Focus 10.

What Did You Find Out? Analyzing and Interpreting

1. Are some forms of a trait more common than others?
2. What can you conclude about the way traits vary among your class members? Why do you think some students show one form of a trait while others show a different form?
3. Do you think most traits are continuous or discrete?

38 MHR • Biological Diversity

Did You Know?

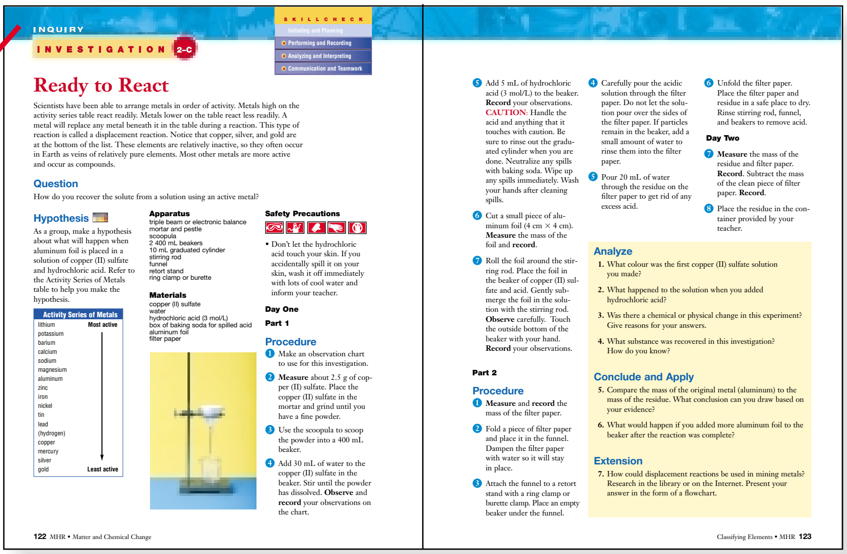
- These features present interesting facts related to science, technology, nature, and the universe.

Find Out Activity

- A short, informal inquiry activity that usually involves hands-on exploration.
- These activities call for simple materials and equipment.
- In these activities, as well as in the investigations, you will use important science process skills: predicting, estimating, hypothesizing, and so on.

Inquiry Investigation

- One-to four-page "formal" labs provide an opportunity to develop science process skills using various equipment and materials.
- These investigations provide a chance to ask questions about science, to develop a hypothesis or a prediction, to make observations, and to obtain results.
- You then analyze your results to determine what they tell you about the topic you are investigating.
- Photographs showing each major step in the Procedure help you to carry out the investigation.
- Safety icons and Safety Precautions alert you to any special precautions you should take to help maintain a safe classroom environment.



INQUIRY
INVESTIGATION 2-C

SKILLCHECK
Initiating and Planning
Performing and Recording
Analyzing and Interpreting
Communication and Teamwork

Ready to React

Scientists have been able to arrange metals in order of activity. Metals high on the activity series table react readily. Metals lower on the table react less readily. A metal will replace any metal beneath it in the table during a reaction. This type of reaction is called a displacement reaction. Notice that copper, silver, and gold are at the bottom of the list. These elements are relatively inactive, so they often occur in Earth as veins of relatively pure elements. Most other metals are more active and occur as compounds.

Question

How do you recover the solute from a solution using an active metal?

Hypothesis

As a group, make a hypothesis about what will happen when aluminum foil is placed in a solution of copper (II) sulfate and hydrochloric acid. Refer to the Activity Series of Metals table to help you make the hypothesis.

Activity Series of Metals
lithium — Most active
potassium
barium
calcium
sodium
magnesium
aluminum
zinc
iron
nickel
tin
lead
(hydrogen)
copper
mercury
silver
gold — Least active

Apparatus
triple beam or electronic balance
mortar and pestle
scoopula
2 400 mL beakers
10 mL graduated cylinder
stirring rod
funnel
retort stand
ring clamp or burette

Materials
copper (II) sulfate
water
hydrochloric acid (3 mol/L)
box of baking soda for spilled acid
aluminum foil
filter paper

Safety Precautions

- Don't let the hydrochloric acid touch your skin. If you accidentally spill it on your skin, wash it off immediately with lots of cool water and inform your teacher.

Day One

Part 1

Procedure

① Make an observation chart to use for this investigation.

② **Measure** about 2.5 g of copper (II) sulfate. Place the copper (II) sulfate in the mortar and grind until you have a fine powder.

③ Use the scoopula to scoop the powder into a 400 mL beaker.

④ Add 30 mL of water to the copper (II) sulfate in the beaker. Stir until the powder has dissolved. **Observe** and **record** your observations on the chart.

⑤ Add 5 mL of hydrochloric acid (3 mol/L) to the beaker. **Record** your observations. CAUTION: Handle the acid and anything that it touches with caution. Be sure to rinse out the graduated cylinder when you are done. Neutralize any spills with baking soda. Wipe up any spills immediately. Wash your hands after cleaning spills.

⑥ Cut a small piece of aluminum foil (4 cm × 4 cm). **Measure** the mass of the foil and **record**.

⑦ Roll the foil around the stirring rod. Place the foil in the beaker of copper (II) sulfate and acid. Gently submerge the foil in the solution with the stirring rod. **Observe** carefully. Touch the outside bottom of the beaker with your hand. **Record** your observations.

Part 2

Procedure

① **Measure** and **record** the mass of the filter paper.

② Fold a piece of filter paper and place it in the funnel. Dampen the filter paper with water so it will stay in place.

③ Attach the funnel to a retort stand with a ring clamp or burette clamp. Place an empty beaker under the funnel.

④ Carefully pour the acidic solution through the filter paper. Do not let the solution pour over the sides of the filter paper. If particles remain in the beaker, add a small amount of water to rinse them into the filter paper.

⑤ Pour 20 mL of water through the residue on the filter paper to get rid of any excess acid.

⑥ Unfold the filter paper. Place the filter paper and residue in a safe place to dry. Rinse stirring rod, funnel, and beakers to remove acid.

Day Two

⑦ **Measure** the mass of the residue and filter paper. **Record**. Subtract the mass of the clean piece of filter paper. **Record**.

⑧ Place the residue in the container provided by your teacher.

Analyze

1. What colour was the first copper (II) sulfate solution you made?
2. What happened to the solution when you added hydrochloric acid?
3. Was there a chemical or physical change in this experiment? Give reasons for your answers.
4. What substance was recovered in this investigation? How do you know?

Conclude and Apply

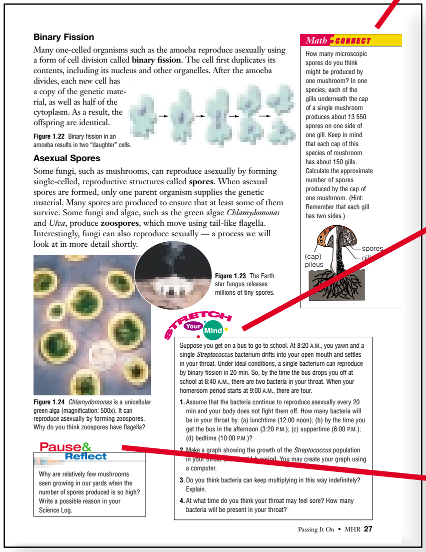
5. Compare the mass of the original metal (aluminum) to the mass of the residue. What conclusion can you draw based on your evidence?
6. What would happen if you added more aluminum foil to the beaker after the reaction was complete?

Extension

7. How could displacement reactions be used in mining metals? Research in the library or on the Internet. Present your answer in the form of a flowchart.

122 MHR • Matter and Chemical Change

Classifying Elements • MHR 123



Binary Fission

Many one-celled organisms such as the amoeba reproduce asexually using a form of cell division called **binary fission.** The cell first duplicates its contents, including its nucleus and other organelles. After the amoeba divides, each new cell has a copy of the genetic material, as well as half of the cytoplasm. As a result, the offspring are identical.

Figure 1.22 Binary fission in an amoeba results in two "daughter" cells.

Asexual Spores

Some fungi, such as mushrooms, can reproduce asexually by forming single-celled, reproductive structures called **spores**. When asexual spores are formed, only one parent organism supplies the genetic material. Many spores are produced to ensure that at least some of them survive. Some fungi and algae, such as the green algae *Chlamydomonas* and *Ulva*, produce **zoospores**, which move using tail-like flagella. Interestingly, fungi can also reproduce sexually — a process we will look at in more detail shortly.

Figure 1.23 The Earth star fungus releases millions of tiny spores.

Figure 1.24 *Chlamydomonas* is a unicellular green alga (magnification: 500x). It can reproduce asexually by forming zoospores. Why do you think zoospores have flagella?

Pause& Reflect

Why are relatively few mushrooms seen growing in our yards when the number of spores produced is so high? Write a possible reason in your Science Log.

Math CONNECT

How many microscopic spores do you think might be produced by one mushroom? In one species, each of the gills underneath the cap of a single mushroom produces about 13 550 spores on one side of one gill. Keep in mind that each cap of this species of mushroom has about 150 gills. Calculate the approximate number of spores produced by the cap of one mushroom. (Hint: Remember that each gill has two sides.)

STRETCH Your Mind

Suppose you get on a bus to go to school. At 8:20 A.M., you yawn and a single *Streptococcus* bacterium drifts into your open mouth and settles in your throat. Under ideal conditions, a single bacterium can reproduce by binary fission in 20 min. So, by the time the bus drops you off at school at 8:40 A.M., there are two bacteria in your throat. When your homeroom period starts at 9:00 A.M., there are four.

1. Assume that the bacteria continue to reproduce asexually every 20 min and your body does not fight them off. How many bacteria will be in your throat by: (a) lunchtime (12:00 noon); (b) by the time you get the bus in the afternoon (3:20 P.M.); (c) suppertime (6:00 P.M.); (d) bedtime (10:00 P.M.)?
2. Make a graph showing the growth of the *Streptococcus* population in your throat over [illegible] h period. You may create your graph using a computer.
3. Do you think bacteria can keep multiplying in this way indefinitely? Explain.
4. At what time do you think your throat may feel sore? How many bacteria will be present in your throat?

Passing It On • MHR **27**

Mathconnect

- Reviews math skills as they are required to do activities.
- Makes connections between your science studies and your math studies.

STRETCH Your Mind

- These brain teasers are often mathematics-related.
- They draw upon your problem-solving skills and your imagination.

Pause& Reflect

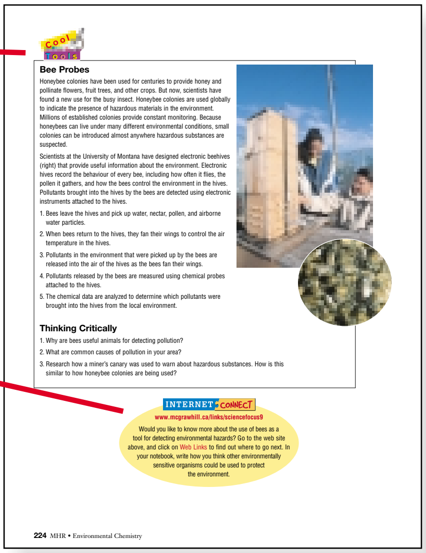
- These items supply opportunities to reflect on what you know (or do not know) and to make connections among ideas throughout the text.
- This recurring feature encourages you to construct your own learning on an ongoing basis and to keep track of how your knowledge is building.

Cool Tools

- This feature provides information about some of the instruments and equipment invented to help humans explore the unknown.
- The information is often related to a variety of occupations and situations.

Internetconnect

- This feature encourages productive use of the Internet by offering content-appropriate sites.
- Web site suggestions will save you time as you do research.



Cool Tools

Bee Probes

Honeybee colonies have been used for centuries to provide honey and pollinate flowers, fruit trees, and other crops. But now, scientists have found a new use for the busy insect. Honeybee colonies are used globally to indicate the presence of hazardous materials in the environment. Millions of established colonies provide constant monitoring. Because honeybees can live under many different environmental conditions, small colonies can be introduced almost anywhere hazardous substances are suspected.

Scientists at the University of Montana have designed electronic beehives (right) that provide useful information about the environment. Electronic hives record the behaviour of every bee, including how often it flies, the pollen it gathers, and how the bees control the environment in the hives. Pollutants brought into the hives by the bees are detected using electronic instruments attached to the hives.

1. Bees leave the hives and pick up water, nectar, pollen, and airborne water particles.
2. When bees return to the hives, they fan their wings to control the air temperature in the hives.
3. Pollutants in the environment that were picked up by the bees are released into the air of the hives as the bees fan their wings.
4. Pollutants released by the bees are measured using chemical probes attached to the hives.
5. The chemical data are analyzed to determine which pollutants were brought into the hives from the local environment.

Thinking Critically

1. Why are bees useful animals for detecting pollution?
2. What are common causes of pollution in your area?
3. Research how a miner's canary was used to warn about hazardous substances. How is this similar to how honeybee colonies are being used?

INTERNET CONNECT

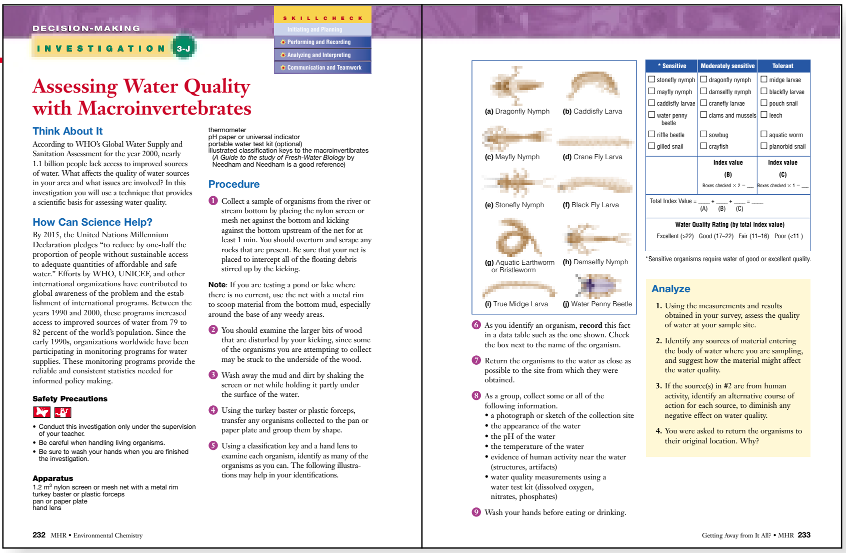
www.mcgrawhill.ca/links/sciencefocus9

Would you like to know more about the use of bees as a tool for detecting environmental hazards? Go to the web site above, and click on Web Links to find out where to go next. In your notebook, write how you think other environmentally sensitive organisms could be used to protect the environment.

224 MHR • Environmental Chemistry

Decision-Making Investigation

- These investigations appear in units that invite you to look at societal issues related to science and/or technology. They present a problem related to the issues you are considering in the unit.
- In these investigations, you will usually work with your group to consider alternatives to the problem and present some alternatives that your group can analyze and discuss.
- These investigations include the heading, "How Can Science Help?". It will remind you to use the scientific concepts, skills, and processes that you are learning to obtain the information you need for your decision-making task.



DECISION-MAKING
INVESTIGATION 3-J

SKILLCHECK
Initiating and Planning
Performing and Recording
Analyzing and Interpreting
Communication and Teamwork

Assessing Water Quality with Macroinvertebrates

Think About It

According to WHO's Global Water Supply and Sanitation Assessment for the year 2000, nearly 1.1 billion people lack access to improved sources of water. What affects the quality of water sources in your area and what issues are involved? In this investigation you will use a technique that provides a scientific basis for assessing water quality.

How Can Science Help?

By 2015, the United Nations Millennium Declaration pledges "to reduce by one-half the proportion of people without sustainable access to adequate quantities of affordable and safe water." Efforts by WHO, UNICEF, and other international organizations have contributed to global awareness of the problem and the establishment of international programs. Between the years 1990 and 2000, these programs increased access to improved sources of water from 79 to 82 percent of the world's population. Since the early 1990s, organizations worldwide have been participating in monitoring programs for water supplies. These monitoring programs provide the reliable and consistent statistics needed for informed policy making.

Safety Precautions

- Conduct this investigation only under the supervision of your teacher.
- Be careful when handling living organisms.
- Be sure to wash your hands when you are finished the investigation.

Apparatus

1.2 m^3 nylon screen or mesh net with a metal rim
turkey baster or plastic forceps
pan or paper plate
hand lens
thermometer
pH paper or universal indicator
portable water test kit (optional)
illustrated classification keys to the macroinvertibrates (*A Guide to the study of Fresh-Water Biology* by Needham and Needham is a good reference)

Procedure

① Collect a sample of organisms from the river or stream bottom by placing the nylon screen or mesh net against the bottom and kicking against the bottom upstream of the net for at least 1 min. You should overturn and scrape any rocks that are present. Be sure that your net is placed to intercept all of the floating debris stirred up by the kicking.

Note: If you are testing a pond or lake where there is no current, use the net with a metal rim to scoop material from the bottom mud, especially around the base of any weedy areas.

② You should examine the larger bits of wood that are disturbed by your kicking, since some of the organisms you are attempting to collect may be stuck to the underside of the wood.

③ Wash away the mud and dirt by shaking the screen or net while holding it partly under the surface of the water.

④ Using the turkey baster or plastic forceps, transfer any organisms collected to the pan or paper plate and group them by shape.

⑤ Using a classification key and a hand lens to examine each organism, identify as many of the organisms as you can. The following illustrations may help in your identifications.

232 MHR • Environmental Chemistry

(a) Dragonfly Nymph (b) Caddisfly Larva
(c) Mayfly Nymph (d) Crane Fly Larva
(e) Stonefly Nymph (f) Black Fly Larva
(g) Aquatic Earthworm or Bristleworm (h) Damselfly Nymph
(i) True Midge Larva (j) Water Penny Beetle

* Sensitive	Moderately sensitive	Tolerant
☐ stonefly nymph	☐ dragonfly nymph	☐ midge larvae
☐ mayfly nymph	☐ damselfly nymph	☐ blackfly larvae
☐ caddisfly larvae	☐ cranefly larvae	☐ pouch snail
☐ water penny beetle	☐ clams and mussels	☐ leech
☐ riffle beetle	☐ sowbug	☐ aquatic worm
☐ gilled snail	☐ crayfish	☐ planorbid snail
	Index value (B) Boxes checked × 2 = __	Index value (C) Boxes checked × 1 = __

Total Index Value = ____ (A) + ____ (B) + ____ (C) = ____

Water Quality Rating (by total index value)
Excellent (>22) Good (17–22) Fair (11–16) Poor (<11)

*Sensitive organisms require water of good or excellent quality.

⑥ As you identify an organism, **record** this fact in a data table such as the one shown. Check the box next to the name of the organism.

⑦ Return the organisms to the water as close as possible to the site from which they were obtained.

⑧ As a group, collect some or all of the following information.
- a photograph or sketch of the collection site
- the appearance of the water
- the pH of the water
- the temperature of the water
- evidence of human activity near the water (structures, artifacts)
- water quality measurements using a water test kit (dissolved oxygen, nitrates, phosphates)

⑨ Wash your hands before eating or drinking.

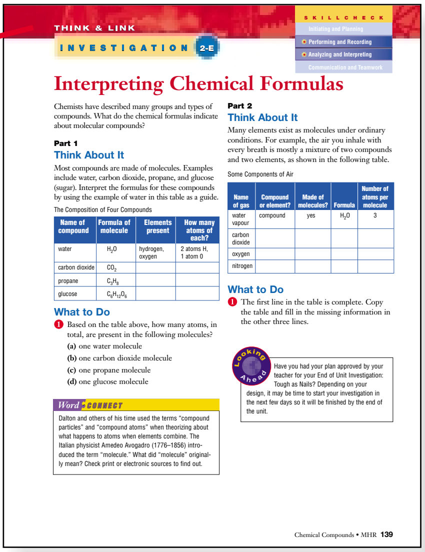
Analyze

1. Using the measurements and results obtained in your survey, assess the quality of water at your sample site.
2. Identify any sources of material entering the body of water where you are sampling, and suggest how the material might affect the water quality.
3. If the source(s) in #2 are from human activity, identify an alternative course of action for each source, to diminish any negative effect on water quality.
4. You were asked to return the organisms to their original location. Why?

Getting Away from It All? • MHR 233

Think & Link Investigation

- These one- to two-page "thought" or "paper-based" investigations let you explore ideas or connections that might be impractical or dangerous in the science classroom.
- These investigations emphasize a variety of skills. These skills include analyzing data, interpreting diagrams or photographs and forming ideas, opinions, or recommendations based on analysis of a societal issue.



THINK & LINK
INVESTIGATION 2-E

SKILLCHECK
Initiating and Planning
Performing and Recording
Analyzing and Interpreting
Communication and Teamwork

Interpreting Chemical Formulas

Chemists have described many groups and types of compounds. What do the chemical formulas indicate about molecular compounds?

Part 1

Think About It

Most compounds are made of molecules. Examples include water, carbon dioxide, propane, and glucose (sugar). Interpret the formulas for these compounds by using the example of water in this table as a guide.

The Composition of Four Compounds

Name of compound	Formula of molecule	Elements present	How many atoms of each?
water	H_2O	hydrogen, oxygen	2 atoms H, 1 atom O
carbon dioxide	CO_2		
propane	C_3H_8		
glucose	$C_6H_{12}O_6$		

What to Do

① Based on the table above, how many atoms, in total, are present in the following molecules?
(a) one water molecule
(b) one carbon dioxide molecule
(c) one propane molecule
(d) one glucose molecule

Word CONNECT

Dalton and others of his time used the terms "compound particles" and "compound atoms" when theorizing about what happens to atoms when elements combine. The Italian physicist Amedeo Avogadro (1776–1856) introduced the term "molecule." What did "molecule" originally mean? Check print or electronic sources to find out.

Part 2

Think About It

Many elements exist as molecules under ordinary conditions. For example, the air you inhale with every breath is mostly a mixture of two compounds and two elements, as shown in the following table.

Some Components of Air

Name of gas	Compound or element?	Made of molecules?	Formula	Number of atoms per molecule
water vapour	compound	yes	H_2O	3
carbon dioxide				
oxygen				
nitrogen				

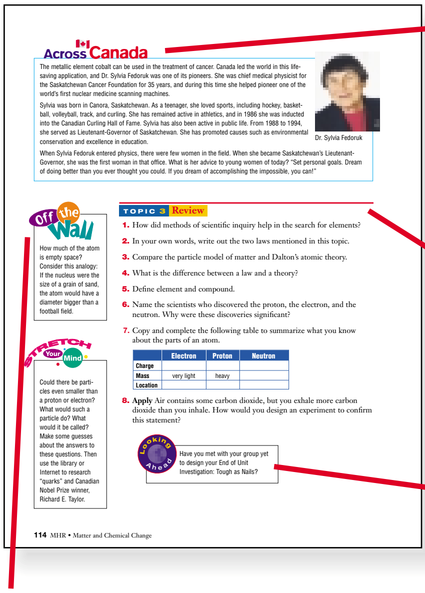
What to Do

① The first line in the table is complete. Copy the table and fill in the missing information in the other three lines.

Looking Ahead

Have you had your plan approved by your teacher for your End of Unit Investigation: Tough as Nails? Depending on your design, it may be time to start your investigation in the next few days so it will be finished by the end of the unit.

Chemical Compounds • MHR 139



Across Canada

The metallic element cobalt can be used in the treatment of cancer. Canada led the world in this life-saving application, and Dr. Sylvia Fedoruk was one of its pioneers. She was chief medical physicist for the Saskatchewan Cancer Foundation for 35 years, and during this time she helped pioneer one of the world's first nuclear medicine scanning machines.

Sylvia was born in Canora, Saskatchewan. As a teenager, she loved sports, including hockey, basketball, volleyball, track, and curling. She has remained active in athletics, and in 1986 she was inducted into the Canadian Curling Hall of Fame. Sylvia has also been active in public life. From 1988 to 1994, she served as Lieutenant-Governor of Saskatchewan. She has promoted causes such as environmental conservation and excellence in education.

Dr. Sylvia Fedoruk

When Sylvia Fedoruk entered physics, there were few women in the field. When she became Saskatchewan's Lieutenant-Governor, she was the first woman in that office. What is her advice to young women of today? "Set personal goals. Dream of doing better than you ever thought you could. If you dream of accomplishing the impossible, you can!"

Off the Wall

How much of the atom is empty space? Consider this analogy: If the nucleus were the size of a grain of sand, the atom would have a diameter bigger than a football field.

STRETCH Your Mind

Could there be particles even smaller than a proton or electron? What would such a particle do? What would it be called? Make some guesses about the answers to these questions. Then use the library or Internet to research "quarks" and Canadian Nobel Prize winner, Richard E. Taylor.

TOPIC 3 Review

1. How did methods of scientific inquiry help in the search for elements?
2. In your own words, write out the two laws mentioned in this topic.
3. Compare the particle model of matter and Dalton's atomic theory.
4. What is the difference between a law and a theory?
5. Define element and compound.
6. Name the scientists who discovered the proton, the electron, and the neutron. Why were these discoveries significant?
7. Copy and complete the following table to summarize what you know about the parts of an atom.

	Electron	Proton	Neutron
Charge			
Mass	very light	heavy	
Location			

8. **Apply** Air contains some carbon dioxide, but you exhale more carbon dioxide than you inhale. How would you design an experiment to confirm this statement?

Looking Ahead

Have you met with your group yet to design your End of Unit Investigation: Tough as Nails?

114 MHR • Matter and Chemical Change

Across Canada

- These "mini-essays" feature information on Canadian scientists involved in important research and discoveries.
- *Across Canada* increases awareness and appreciation of the work of Canadian scientists. The essays also provide role models for those of you interested in careers or further study in science.

Topic Review

- A set of review questions appears at the end of each Topic.
- These questions provide opportunities for ongoing self-assessment.
- "Apply" and "Thinking Critically" questions give you additional challenges.

Looking Ahead

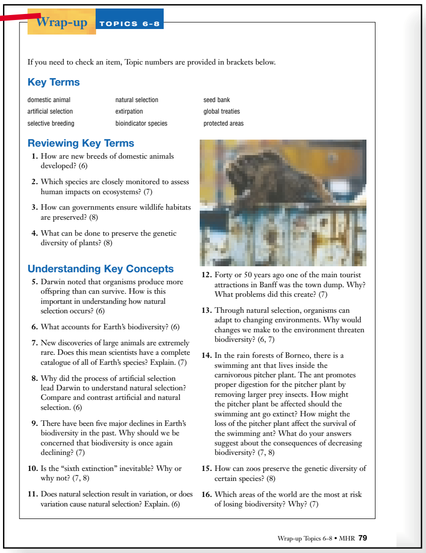
- This feature reminds you to keep planning your end-of-unit challenge.

Off the Wall

- This item features intriguing situations, odd events, or weird facts.
- Ideas for connecting science with other curriculum areas are often included.

Wrap-up

- Located at the end of each cluster of Topics, this page provides self-assessment opportunities as you look back over two or three Topics.
- It gives parents or guardians an overview of what you have accomplished.



Wrap-up TOPICS 6–8

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

domestic animal
artificial selection
selective breeding
natural selection
extirpation
bioindicator species
seed bank
global treaties
protected areas

Reviewing Key Terms

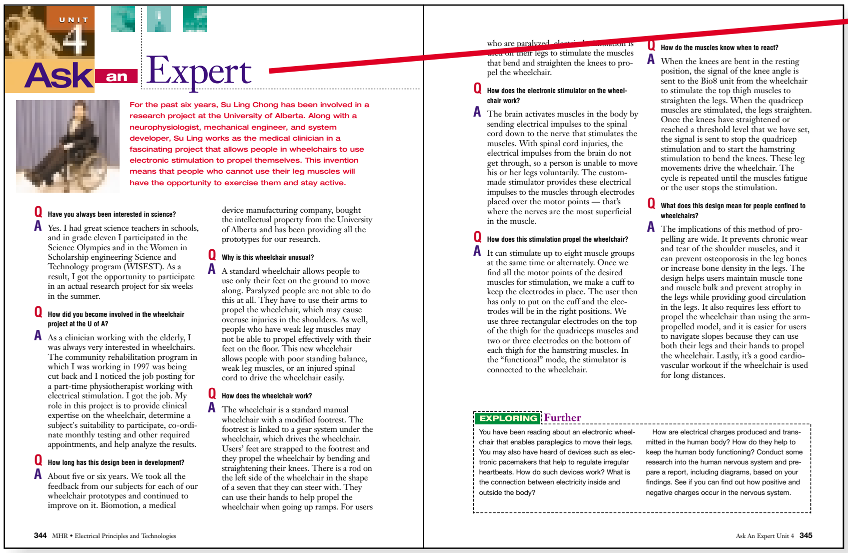
1. How are new breeds of domestic animals developed? (6)
2. Which species are closely monitored to assess human impacts on ecosystems? (7)
3. How can governments ensure wildlife habitats are preserved? (8)
4. What can be done to preserve the genetic diversity of plants? (8)

Understanding Key Concepts

5. Darwin noted that organisms produce more offspring than can survive. How is this important in understanding how natural selection occurs? (6)
6. What accounts for Earth's biodiversity? (6)
7. New discoveries of large animals are extremely rare. Does this mean scientists have a complete catalogue of all of Earth's species? Explain. (7)
8. Why did the process of artificial selection lead Darwin to understand natural selection? Compare and contrast artificial and natural selection. (6)
9. There have been five major declines in Earth's biodiversity in the past. Why should we be concerned that biodiversity is once again declining? (7)
10. Is the "sixth extinction" inevitable? Why or why not? (7, 8)
11. Does natural selection result in variation, or does variation cause natural selection? Explain. (6)
12. Forty or 50 years ago one of the main tourist attractions in Banff was the town dump. Why? What problems did this create? (7)
13. Through natural selection, organisms can adapt to changing environments. Why would changes we make to the environment threaten biodiversity? (6, 7)
14. In the rain forests of Borneo, there is a swimming ant that lives inside the carnivorous pitcher plant. The ant promotes proper digestion for the pitcher plant by removing larger prey insects. How might the pitcher plant be affected should the swimming ant go extinct? How might the loss of the pitcher plant affect the survival of the swimming ant? What do your answers suggest about the consequences of decreasing biodiversity? (7, 8)
15. How can zoos preserve the genetic diversity of certain species? (8)
16. Which areas of the world are the most at risk of losing biodiversity? Why? (7)

Wrap-up Topics 6–8 • MHR **79**

End-of-Unit Features



UNIT 4

Ask an Expert

For the past six years, Su Ling Chong has been involved in a research project at the University of Alberta. Along with a neurophysiologist, mechanical engineer, and system developer, Su Ling works as the medical clinician in a fascinating project that allows people in wheelchairs to use electronic stimulation to propel themselves. This invention means that people who cannot use their leg muscles will have the opportunity to exercise them and stay active.

Q **Have you always been interested in science?**

A Yes. I had great science teachers in schools, and in grade eleven I participated in the Science Olympics and in the Women in Scholarship engineering Science and Technology program (WISEST). As a result, I got the opportunity to participate in an actual research project for six weeks in the summer.

Q **How did you become involved in the wheelchair project at the U of A?**

A As a clinician working with the elderly, I was always very interested in wheelchairs. The community rehabilitation program in which I was working in 1997 was being cut back and I noticed the job posting for a part-time physiotherapist working with electrical stimulation. I got the job. My role in this project is to provide clinical expertise on the wheelchair, determine a subject's suitability to participate, co-ordinate monthly testing and other required appointments, and help analyze the results.

Q **How long has this design been in development?**

A About five or six years. We took all the feedback from our subjects for each of our wheelchair prototypes and continued to improve on it. Biomotion, a medical device manufacturing company, bought the intellectual property from the University of Alberta and has been providing all the prototypes for our research.

Q **Why is this wheelchair unusual?**

A A standard wheelchair allows people to use only their feet on the ground to move along. Paralyzed people are not able to do this at all. They have to use their arms to propel the wheelchair, which may cause overuse injuries in the shoulders. As well, people who have weak leg muscles may not be able to propel effectively with their feet on the floor. This new wheelchair allows people with poor standing balance, weak leg muscles, or an injured spinal cord to drive the wheelchair easily.

Q **How does the wheelchair work?**

A The wheelchair is a standard manual wheelchair with a modified footrest. The footrest is linked to a gear system under the wheelchair, which drives the wheelchair. Users' feet are strapped to the footrest and they propel the wheelchair by bending and straightening their knees. There is a rod on the left side of the wheelchair in the shape of a seven that they can steer with. They can use their hands to help propel the wheelchair when going up ramps. For users who are paralyzed, electrical stimulation is used on their legs to stimulate the muscles that bend and straighten the knees to propel the wheelchair.

Q **How does the electronic stimulator on the wheelchair work?**

A The brain activates muscles in the body by sending electrical impulses to the spinal cord down to the nerve that stimulates the muscles. With spinal cord injuries, the electrical impulses from the brain do not get through, so a person is unable to move his or her legs voluntarily. The custom-made stimulator provides these electrical impulses to the muscles through electrodes placed over the motor points — that's where the nerves are the most superficial in the muscle.

Q **How does this stimulation propel the wheelchair?**

A It can stimulate up to eight muscle groups at the same time or alternately. Once we find all the motor points of the desired muscles for stimulation, we make a cuff to keep the electrodes in place. The user then has only to put on the cuff and the electrodes will be in the right positions. We use three rectangular electrodes on the top of the thigh for the quadriceps muscles and two or three electrodes on the bottom of each thigh for the hamstring muscles. In the "functional" mode, the stimulator is connected to the wheelchair.

Q **How do the muscles know when to react?**

A When the knees are bent in the resting position, the signal of the knee angle is sent to the Bio8 unit from the wheelchair to stimulate the top thigh muscles to straighten the legs. When the quadricep muscles are stimulated, the legs straighten. Once the knees have straightened or reached a threshold level that we have set, the signal is sent to stop the quadricep stimulation and to start the hamstring stimulation to bend the knees. These leg movements drive the wheelchair. The cycle is repeated until the muscles fatigue or the user stops the stimulation.

Q **What does this design mean for people confined to wheelchairs?**

A The implications of this method of propelling are wide. It prevents chronic wear and tear of the shoulder muscles, and it can prevent osteoporosis in the leg bones or increase bone density in the legs. The design helps users maintain muscle tone and muscle bulk and prevent atrophy in the legs while providing good circulation in the legs. It also requires less effort to propel the wheelchair than using the arm-propelled model, and it is easier for users to navigate slopes because they can use both their legs and their hands to propel the wheelchair. Lastly, it's a good cardiovascular workout if the wheelchair is used for long distances.

EXPLORING Further

You have been reading about an electronic wheelchair that enables paraplegics to move their legs. You may also have heard of devices such as electronic pacemakers that help to regulate irregular heartbeats. How do such devices work? What is the connection between electricity inside and outside the body?

How are electrical charges produced and transmitted in the human body? How do they help to keep the human body functioning? Conduct some research into the human nervous system and prepare a report, including diagrams, based on your findings. See if you can find out how positive and negative charges occur in the nervous system.

344 MHR • Electrical Principles and Technologies

Ask An Expert Unit 4 **345**

Ask an Expert

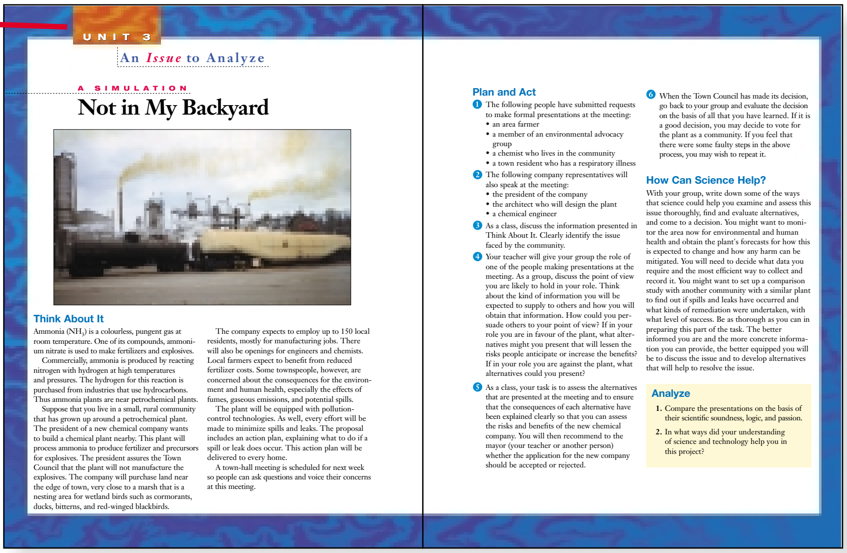
- Experts in every area of science and technology are working to understand better how the world "works" and to try to find solutions to difficult problems. The *Ask an Expert* feature at the end of each unit is an interview with one of these many people.
- After the interviews, you will have a chance to do an activity that is related to the kind of work the expert does.

End-of-Unit Challenge:
Project
An Issue to Analyze
Design Your Own Investigation

- Each unit in *SCIENCEFOCUS 9* presents a challenge that will provide an opportunity for you and your group to use what you have learned throughout the unit. These challenges will take three different forms, depending on the emphasis of the unit.
- Early in the unit, your teacher will ask you to begin to consider how you might research, organize, plan, and complete your end-of-unit challenge.

An Issue to Analyze

- You, your community, and society in general face complex issues in today's world. Understanding science and technology cannot provide a "correct" answer to the problems these issues present, but understanding will lead to more informed decisions. *An Issue to Analyze* gives you a chance to start thinking now about how you can use your understanding of Science Skills and Concepts to help make the best decisions for yourself and your community, today and in the future.
- This feature takes the form of either a simulation or a debate.



UNIT 3

An *Issue* to Analyze

A SIMULATION

Not in My Backyard

Think About It

Ammonia (NH_3) is a colourless, pungent gas at room temperature. One of its compounds, ammonium nitrate is used to make fertilizers and explosives.

Commercially, ammonia is produced by reacting nitrogen with hydrogen at high temperatures and pressures. The hydrogen for this reaction is purchased from industries that use hydrocarbons. Thus ammonia plants are near petrochemical plants.

Suppose that you live in a small, rural community that has grown up around a petrochemical plant. The president of a new chemical company wants to build a chemical plant nearby. This plant will process ammonia to produce fertilizer and precursors for explosives. The president assures the Town Council that the plant will not manufacture the explosives. The company will purchase land near the edge of town, very close to a marsh that is a nesting area for wetland birds such as cormorants, ducks, bitterns, and red-winged blackbirds.

The company expects to employ up to 150 local residents, mostly for manufacturing jobs. There will also be openings for engineers and chemists. Local farmers expect to benefit from reduced fertilizer costs. Some townspeople, however, are concerned about the consequences for the environment and human health, especially the effects of fumes, gaseous emissions, and potential spills.

The plant will be equipped with pollution-control technologies. As well, every effort will be made to minimize spills and leaks. The proposal includes an action plan, explaining what to do if a spill or leak does occur. This action plan will be delivered to every home.

A town-hall meeting is scheduled for next week so people can ask questions and voice their concerns at this meeting.

Plan and Act

① The following people have submitted requests to make formal presentations at the meeting:
- an area farmer
- a member of an environmental advocacy group
- a chemist who lives in the community
- a town resident who has a respiratory illness

② The following company representatives will also speak at the meeting:
- the president of the company
- the architect who will design the plant
- a chemical engineer

③ As a class, discuss the information presented in Think About It. Clearly identify the issue faced by the community.

④ Your teacher will give your group the role of one of the people making presentations at the meeting. As a group, discuss the point of view you are likely to hold in your role. Think about the kind of information you will be expected to supply to others and how you will obtain that information. How could you persuade others to your point of view? If in your role you are in favour of the plant, what alternatives might you present that will lessen the risks people anticipate or increase the benefits? If in your role you are against the plant, what alternatives could you present?

⑤ As a class, your task is to assess the alternatives that are presented at the meeting and to ensure that the consequences of each alternative have been explained clearly so that you can assess the risks and benefits of the new chemical company. You will then recommend to the mayor (your teacher or another person) whether the application for the new company should be accepted or rejected.

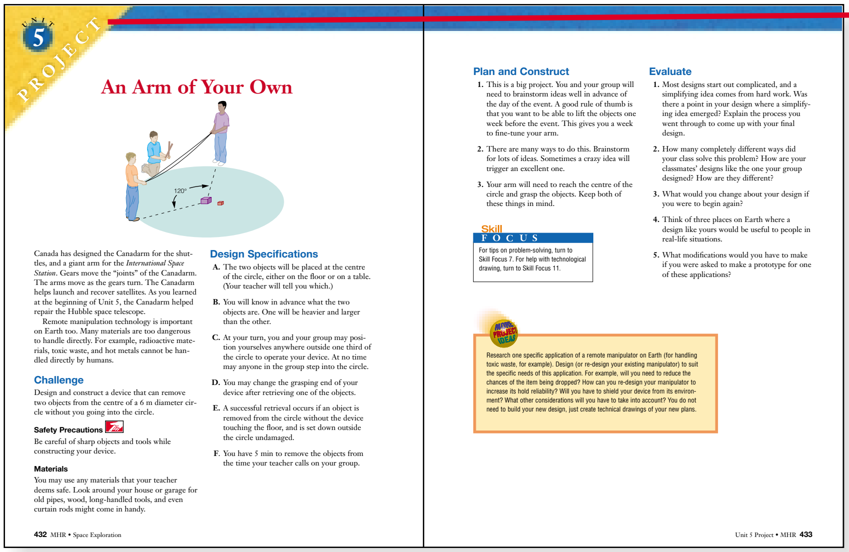
⑥ When the Town Council has made its decision, go back to your group and evaluate the decision on the basis of all that you have learned. If it is a good decision, you may decide to vote for the plant as a community. If you feel that there were some faulty steps in the above process, you may wish to repeat it.

How Can Science Help?

With your group, write down some of the ways that science could help you examine and assess this issue thoroughly, find and evaluate alternatives, and come to a decision. You might want to monitor the area now for environmental and human health and obtain the plant's forecasts for how this is expected to change and how any harm can be mitigated. You will need to decide what data you require and the most efficient way to collect and record it. You might want to set up a comparison study with another community with a similar plant to find out if spills and leaks have occurred and what kinds of remediation were undertaken, with what level of success. Be as thorough as you can in preparing this part of the task. The better informed you are and the more concrete information you can provide, the better equipped you will be to discuss the issue and to develop alternatives that will help to resolve the issue.

Analyze

1. Compare the presentations on the basis of their scientific soundness, logic, and passion.
2. In what ways did your understanding of science and technology help you in this project?



UNIT 5 PROJECT

An Arm of Your Own

Canada has designed the Canadarm for the shuttles, and a giant arm for the *International Space Station*. Gears move the "joints" of the Canadarm. The arms move as the gears turn. The Canadarm helps launch and recover satellites. As you learned at the beginning of Unit 5, the Canadarm helped repair the Hubble space telescope.

Remote manipulation technology is important on Earth too. Many materials are too dangerous to handle directly. For example, radioactive materials, toxic waste, and hot metals cannot be handled directly by humans.

Challenge

Design and construct a device that can remove two objects from the centre of a 6 m diameter circle without you going into the circle.

Safety Precautions

Be careful of sharp objects and tools while constructing your device.

Materials

You may use any materials that your teacher deems safe. Look around your house or garage for old pipes, wood, long-handled tools, and even curtain rods might come in handy.

Design Specifications

A. The two objects will be placed at the centre of the circle, either on the floor or on a table. (Your teacher will tell you which.)

B. You will know in advance what the two objects are. One will be heavier and larger than the other.

C. At your turn, you and your group may position yourselves anywhere outside one third of the circle to operate your device. At no time may anyone in the group step into the circle.

D. You may change the grasping end of your device after retrieving one of the objects.

E. A successful retrieval occurs if an object is removed from the circle without the device touching the floor, and is set down outside the circle undamaged.

F. You have 5 min to remove the objects from the time your teacher calls on your group.

432 MHR • Space Exploration

Plan and Construct

1. This is a big project. You and your group will need to brainstorm ideas well in advance of the day of the event. A good rule of thumb is that you want to be able to lift the objects one week before the event. This gives you a week to fine-tune your arm.
2. There are many ways to do this. Brainstorm for lots of ideas. Sometimes a crazy idea will trigger an excellent one.
3. Your arm will need to reach the centre of the circle and grasp the objects. Keep both of these things in mind.

Skill FOCUS

For tips on problem-solving, turn to Skill Focus 7. For help with technological drawing, turn to Skill Focus 11.

Evaluate

1. Most designs start out complicated, and a simplifying idea comes from hard work. Was there a point in your design where a simplifying idea emerged? Explain the process you went through to come up with your final design.
2. How many completely different ways did your class solve this problem? How are your classmates' designs like the one your group designed? How are they different?
3. What would you change about your design if you were to begin again?
4. Think of three places on Earth where a design like yours would be useful to people in real-life situations.
5. What modifications would you have to make if you were asked to make a prototype for one of these applications?

MORE PROJECT IDEAS

Research one specific application of a remote manipulator on Earth (for handling toxic waste, for example). Design (or re-design your existing manipulator) to suit the specific needs of this application. For example, will you need to reduce the chances of the item being dropped? How can you re-design your manipulator to increase its hold reliability? Will you have to shield your device from its environment? What other considerations will you have to take into account? You do not need to build your new design, just create technical drawings of your new plans.

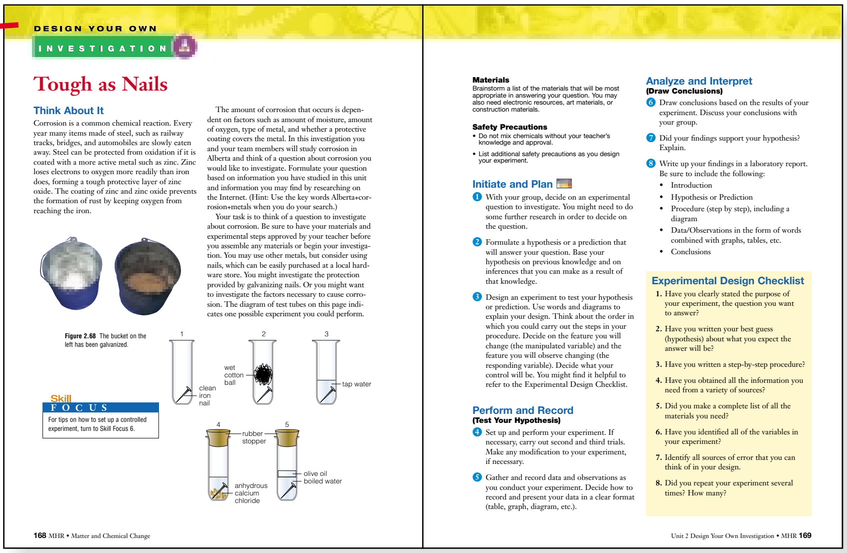
Unit 5 Project • MHR 433

Project

- A Unit Project gives you a chance to use key ideas and skills from the unit to create your own device, system, model, or (in Unit 4) a research presentation.
- You will complete the project as part of a team.
- *More Project Ideas* offers additional suggestions for enjoyable ways to demonstrate your learning.

Design Your Own Investigation

- As you work through each unit, you will find answers to some science questions. You will also think of more questions of your own.
- The Design Your Own Investigation challenge enables you to develop an experimental procedure to answer your question. You will work with your group to come up with a hypothesis or a prediction that you can test. Your question will be based on what you have learned in the unit.
- You will design and carry out your experimental procedure and then evaluate the results.



DESIGN YOUR OWN INVESTIGATION

Tough as Nails

Think About It

Corrosion is a common chemical reaction. Every year many items made of steel, such as railway tracks, bridges, and automobiles are slowly eaten away. Steel can be protected from oxidation if it is coated with a more active metal such as zinc. Zinc loses electrons to oxygen more readily than iron does, forming a tough protective layer of zinc oxide. The coating of zinc and zinc oxide prevents the formation of rust by keeping oxygen from reaching the iron.

The amount of corrosion that occurs is dependent on factors such as amount of moisture, amount of oxygen, type of metal, and whether a protective coating covers the metal. In this investigation you and your team members will study corrosion in Alberta and think of a question about corrosion you would like to investigate. Formulate your question based on information you have studied in this unit and information you may find by researching on the Internet. (Hint: Use the key words Alberta+corrosion+metals when you do your search.)

Your task is to think of a question to investigate about corrosion. Be sure to have your materials and experimental steps approved by your teacher before you assemble any materials or begin your investigation. You may use other metals, but consider using nails, which can be easily purchased at a local hardware store. You might investigate the protection provided by galvanizing nails. Or you might want to investigate the factors necessary to cause corrosion. The diagram of test tubes on this page indicates one possible experiment you could perform.

Figure 2.68 The bucket on the left has been galvanized.

Skill FOCUS

For tips on how to set up a controlled experiment, turn to Skill Focus 6.

168 MHR • Matter and Chemical Change

Materials

Brainstorm a list of the materials that will be most appropriate in answering your question. You may also need electronic resources, art materials, or construction materials.

Safety Precautions

- Do not mix chemicals without your teacher's knowledge and approval.
- List additional safety precautions as you design your experiment.

Initiate and Plan

① With your group, decide on an experimental question to investigate. You might need to do some further research in order to decide on the question.

② Formulate a hypothesis or a prediction that will answer your question. Base your hypothesis on previous knowledge and on inferences that you can make as a result of that knowledge.

③ Design an experiment to test your hypothesis or prediction. Use words and diagrams to explain your design. Think about the order in which you could carry out the steps in your procedure. Decide on the feature you will change (the manipulated variable) and the feature you will observe changing (the responding variable). Decide what your control will be. You might find it helpful to refer to the Experimental Design Checklist.

Perform and Record
(Test Your Hypothesis)

④ Set up and perform your experiment. If necessary, carry out second and third trials. Make any modification to your experiment, if necessary.

⑤ Gather and record data and observations as you conduct your experiment. Decide how to record and present your data in a clear format (table, graph, diagram, etc.).

Analyze and Interpret
(Draw Conclusions)

⑥ Draw conclusions based on the results of your experiment. Discuss your conclusions with your group.

⑦ Did your findings support your hypothesis? Explain.

⑧ Write up your findings in a laboratory report. Be sure to include the following:
- Introduction
- Hypothesis or Prediction
- Procedure (step by step), including a diagram
- Data/Observations in the form of words combined with graphs, tables, etc.
- Conclusions

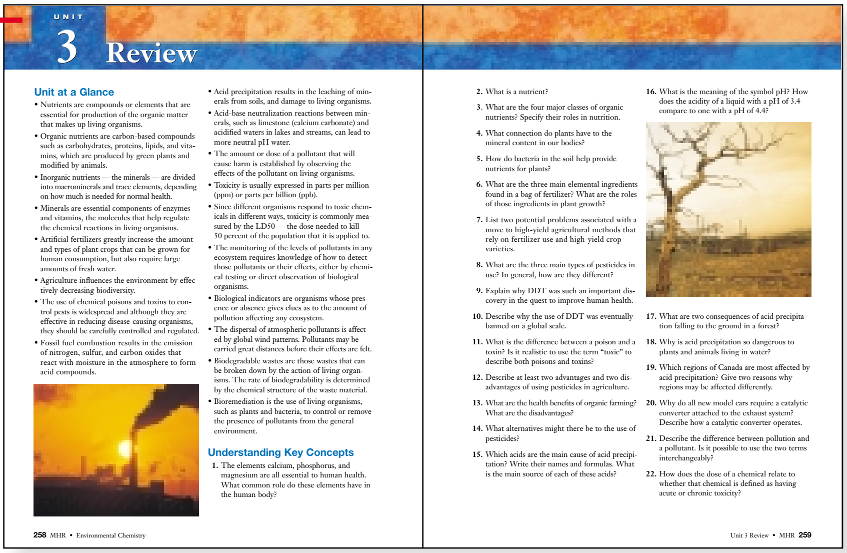
Experimental Design Checklist

1. Have you clearly stated the purpose of your experiment, the question you want to answer?
2. Have you written your best guess (hypothesis) about what you expect the answer will be?
3. Have you written a step-by-step procedure?
4. Have you obtained all the information you need from a variety of sources?
5. Did you make a complete list of all the materials you need?
6. Have you identified all of the variables in your experiment?
7. Identify all sources of error that you can think of in your design.
8. Did you repeat your experiment several times? How many?

Unit 2 Design Your Own Investigation • MHR 169

Unit Review

- This final wrap-up of each unit reviews basic concepts, skills of inquiry and communication, and skills relating science to technology, society, and the environment.
- These questions help you recall, think about, and apply what you have learned.



UNIT 3 Review

Unit at a Glance

- Nutrients are compounds or elements that are essential for production of the organic matter that makes up living organisms.
- Organic nutrients are carbon-based compounds such as carbohydrates, proteins, lipids, and vitamins, which are produced by green plants and modified by animals.
- Inorganic nutrients — the minerals — are divided into macrominerals and trace elements, depending on how much is needed for normal health.
- Minerals are essential components of enzymes and vitamins, the molecules that help regulate the chemical reactions in living organisms.
- Artificial fertilizers greatly increase the amount and types of plant crops that can be grown for human consumption, but also require large amounts of fresh water.
- Agriculture influences the environment by effectively decreasing biodiversity.
- The use of chemical poisons and toxins to control pests is widespread and although they are effective in reducing disease-causing organisms, they should be carefully controlled and regulated.
- Fossil fuel combustion results in the emission of nitrogen, sulfur, and carbon oxides that react with moisture in the atmosphere to form acid compounds.
- Acid precipitation results in the leaching of minerals from soils, and damage to living organisms.
- Acid-base neutralization reactions between minerals, such as limestone (calcium carbonate) and acidified waters in lakes and streams, can lead to more neutral pH water.
- The amount or dose of a pollutant that will cause harm is established by observing the effects of the pollutant on living organisms.
- Toxicity is usually expressed in parts per million (ppm) or parts per billion (ppb).
- Since different organisms respond to toxic chemicals in different ways, toxicity is commonly measured by the LD50 — the dose needed to kill 50 percent of the population that it is applied to.
- The monitoring of the levels of pollutants in any ecosystem requires knowledge of how to detect those pollutants or their effects, either by chemical testing or direct observation of biological organisms.
- Biological indicators are organisms whose presence or absence gives clues as to the amount of pollution affecting any ecosystem.
- The dispersal of atmospheric pollutants is affected by global wind patterns. Pollutants may be carried great distances before their effects are felt.
- Biodegradable wastes are those wastes that can be broken down by the action of living organisms. The rate of biodegradability is determined by the chemical structure of the waste material.
- Bioremediation is the use of living organisms, such as plants and bacteria, to control or remove the presence of pollutants from the general environment.

Understanding Key Concepts

1. The elements calcium, phosphorus, and magnesium are all essential to human health. What common role do these elements have in the human body?
2. What is a nutrient?
3. What are the four major classes of organic nutrients? Specify their roles in nutrition.
4. What connection do plants have to the mineral content in our bodies?
5. How do bacteria in the soil help provide nutrients for plants?
6. What are the three main elemental ingredients found in a bag of fertilizer? What are the roles of those ingredients in plant growth?
7. List two potential problems associated with a move to high-yield agricultural methods that rely on fertilizer use and high-yield crop varieties.
8. What are the three main types of pesticides in use? In general, how are they different?
9. Explain why DDT was such an important discovery in the quest to improve human health.
10. Describe why the use of DDT was eventually banned on a global scale.
11. What is the difference between a poison and a toxin? Is it realistic to use the term “toxic” to describe both poisons and toxins?
12. Describe at least two advantages and two disadvantages of using pesticides in agriculture.
13. What are the health benefits of organic farming? What are the disadvantages?
14. What alternatives might there be to the use of pesticides?
15. Which acids are the main cause of acid precipitation? Write their names and formulas. What is the main source of each of these acids?
16. What is the meaning of the symbol pH? How does the acidity of a liquid with a pH of 3.4 compare to one with a pH of 4.4?
17. What are two consequences of acid precipitation falling to the ground in a forest?
18. Why is acid precipitation so dangerous to plants and animals living in water?
19. Which regions of Canada are most affected by acid precipitation? Give two reasons why regions may be affected differently.
20. Why do all new model cars require a catalytic converter attached to the exhaust system? Describe how a catalytic converter operates.
21. Describe the difference between pollution and a pollutant. Is it possible to use the two terms interchangeably?
22. How does the dose of a chemical relate to whether that chemical is defined as having acute or chronic toxicity?

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Other Important Features

Word CONNECT

- Word origins and a variety of language activities provide links to language arts.

Career CONNECT

- Portrays people with various levels of education making practical use of science and technology in their jobs.

Computer CONNECT

- Highlights opportunities where using spreadsheets or data base applications would be helpful.

Design Your Own

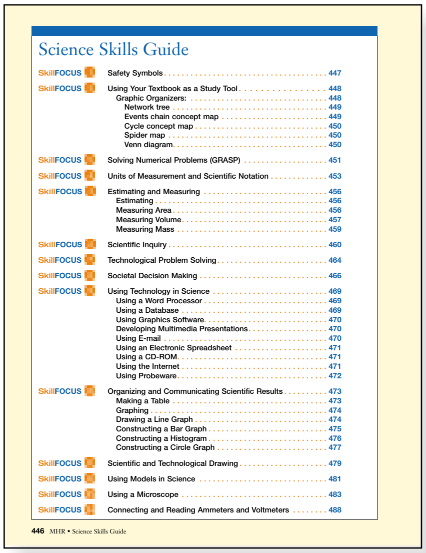
- This signals opportunities in investigations, activities, Topic Reviews, and Topic Wrap-ups for you to plan, design, and conduct your own experimental investigations.

EXTENSION

- This signals material that adds extra interest and understanding to the concepts you are learning.

Wrapping Up the Tour

At the back of ***SCIENCEFOCUS 9***, you will find some additional features to help you review and develop skills and knowledge that you will need to be successful in this course. Are you having trouble with graphing? Would you like help setting up a data table? Have you forgotten how to make a concept map? Do you need a reminder about scientific notation or the metric system? The *Science Skills Guide* will help you review or improve your skills. A *Glossary* provides all the key vocabulary for the whole course, and an *Index* will help you find your way to a topic.



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Special Icons

The co-operative group work icon alerts you to opportunities to work within a group. The safety icons are extremely important because they alert you to any safety precautions you must take, for example, the need for safety goggles or a lab apron. Other safety icons used in this book are shown on page 447. Make certain you become familiar with what they mean, and make sure that you follow their precautions.

Instant Practice — Feature Hunt

To acquaint yourself further with your textbook before you start using it, see if you can find some of the features it contains. Work with a partner.

1. Find the following features. Briefly tell what each feature is about and record the page number where you found it.
  (a) a *Pause & Reflect* in Unit 3
  (b) an *Off the Wall* in Unit 2
  (c) a *CareerConnect* in Unit 4
  (d) a *DidYouKnow?* in Unit 1
  (e) an *Inquiry Investigation* entitled "Drop-by-Drop Neutralization" in Unit 3
  (f) a *Find Out Activity* entitled "Light That Bulb?" in Unit 4
  (g) an *Across Canada* in Unit 2

2. Find these words and their meanings.
  (a) speciation (Unit 1)
  (b) bioremediation (Unit 3)
  (c) interferometry (Unit 5)
  (d) reactants (Unit 2)
  (e) resistor (Unit 4)
  (f) cycle concept map (Skill Focus 2)
  (g) bar graph (Skill Focus 10)

Extension

3. Prepare your own feature hunt for a classmate to do.

Safety in Your Science Classroom

Become familiar with the following safety rules and procedures. It is up to you to use them and your teacher's instructions to make your activities and investigations in ***SCIENCEFOCUS 9*** safe and enjoyable. Your teacher will give you specific information about any other special safety rules to be used in your school.

1. **General Rules**
   - Listen carefully to any instructions your teacher gives you.
   - Inform your teacher if you have any allergies, medical conditions, or other physical problems that could affect your work in the science classroom. Tell your teacher if you wear contact lenses or a hearing aid.
   - Obtain your teacher's approval before beginning any activity or investigation you have designed yourself.
   - Know the location and proper use of the nearest fire extinguisher, fire blanket, first aid kit, and fire alarm.
2. **Before Each Activity or Investigation**
   - Before starting any activity or investigation, read all of it carefully. If you do not understand how to do a step, ask your teacher for help.
   - Be sure you have read and understand the *Safety Precautions*.
   - Begin an activity only after your teacher tells you to start.
3. **Special Dress Precautions**
   - When you are directed to do so, wear protective clothing, such as a lab apron, safety goggles, and/or safety gloves. Always wear protective clothing when you are using materials that could pose a safety problem, such as when you are using unidentified materials, or when you are heating anything.
   - Tie back long hair, and avoid wearing scarves, ties, long necklaces, and earrings.
4. **Doing Activities and Investigations**
   - Work carefully with a partner and make sure your work area is clear.
   - Handle equipment and materials carefully.
   - Make sure stools and chairs are resting securely on the floor.
   - If other students are doing something that you consider dangerous, report it to your teacher.
   - Do not chew gum, eat, or drink in your science classroom.
   - Do not taste any substances or draw any material into a tube with your mouth.
   - Make sure you understand all safety labels on school materials or those you bring from home. Familiarize yourself, as well, with the WHMIS symbols and the special safety symbols used in this book found on page 445.
   - Be careful when carrying equipment for an activity or investigation. Carry only one object or container at a time.
   - Be aware of others during activities and investigations. Make room for students who may be carrying equipment to their work station.

5.Sharp Object Precautions

- Always cut away from yourself and others when using a knife or razor blade.
- Always keep the pointed end of scissors or any pointed object facing away from yourself and others if you have to walk with such objects.
- If you notice sharp or jagged edges on any equipment, take special care with it and report it to your teacher.
- Dispose of broken glass as your teacher directs.

6. Electrical Equipment Precautions

- Make sure your hands are dry when touching electrical cords, plugs, or sockets.
- Pull the plug, not the cord when unplugging electrical equipment. Report damaged equipment or frayed cords to your teacher.
- Place electrical cords in places where people will not trip over them.

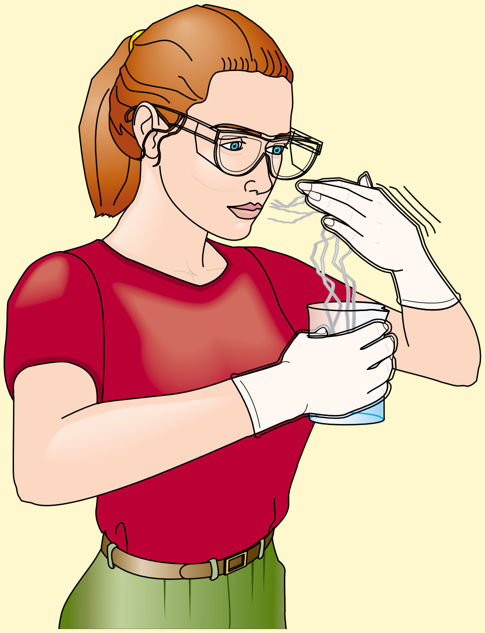
7. Heat Source Precautions

- Wear safety goggles, heat-resistant safety gloves, and any other safety equipment that the text or your teacher suggests, when heating any item.
- Always use heat-proof containers.
- Do not use broken or cracked containers.
- Point the open end of a container that is being heated away from yourself and others.
- Do not allow a container to boil dry.
- Handle hot objects carefully. Be especially careful with a hot plate that might look as though it has cooled down.
- If you use a Bunsen burner, make sure you understand how to light and use it safely.
- If you do receive a burn, inform your teacher. Apply cold water to the burned area immediately.

8. Chemical Precautions

- If any part of your body comes in contact with a potentially dangerous substance, wash the area immediately and thoroughly with water. If you get anything in your eyes, do not touch them. Wash them immediately and continuously for 15 min, and inform your teacher.

Use this method to smell a substance in the laboratory.



- Always handle substances carefully. If you are asked to smell a substance, never smell it directly. Hold the container slightly in front of and beneath your nose, and waft the fumes toward your nostrils, as shown here.
- Hold containers away from your face when pouring liquids, as shown on the next page.

9. Working with Living Things

On a field trip:

- Try not to disturb the area any more than is absolutely necessary.
- If you move something, do it carefully, and always replace it carefully.
- If you are asked to remove plant material, remove it gently, and take as little as possible.

In the classroom:

- Treat living creatures with respect.
- Make sure that living creatures receive humane treatment while they are in your care.
- If possible, return living creatures to their natural environment when your work is complete.

10. Cleaning Up in the Science Classroom

- Clean up any spills, according to your teacher's instructions.
- Clean equipment before you put it away.
- Wash your hands thoroughly after doing an activity or an investigation.
- Dispose of materials as directed by your teacher. Never discard materials in the sink unless your teacher requests it.

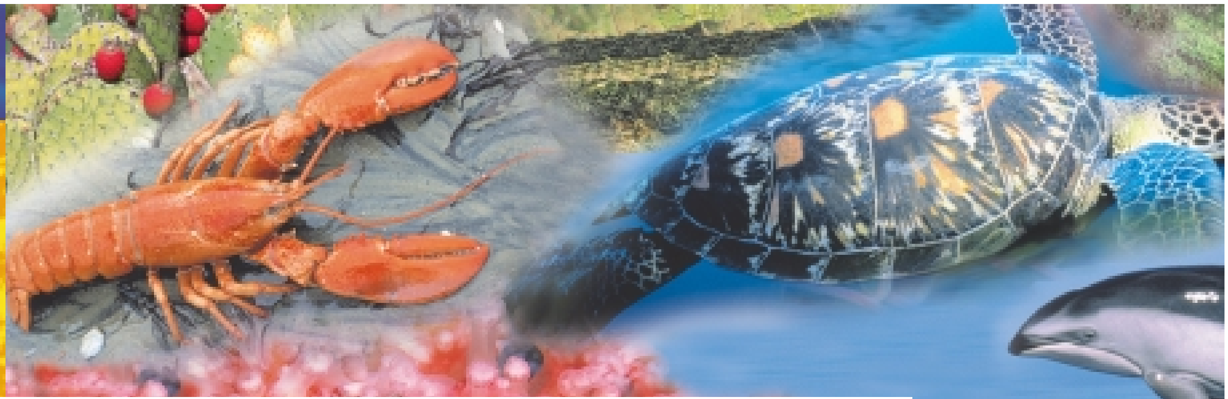
11. Technology Projects

- Use tools safely to cut, join, and shape objects.
- Handle modelling clay correctly. Wash your hands after using modelling clay.
- Follow proper procedures when comparing mechanical systems and their operations.
- Use special care when observing and working with objects in motion (e.g., objects that spin, swing, bounce, or vibrate; gears and pulleys; and elevated objects).
- Do not use power equipment such as drills, sanders, saws, and lathes unless you have specialized training in handling such tools. Make sure you obtain information and support for designing and building devices from a specialist teacher in this area for all *Problem-Solving Investigations* and *Unit Projects* that ask you to design and build models and/or devices or structures.

Instant Practice

1. Select four or five of the main safety points listed and use them to create a video that communicates the message of the importance of safety.
2. Use the *SkillFocus* on page 447 to ensure that you are familiar with all of the safety icons used in this textbook and in workplaces.

UNIT 1



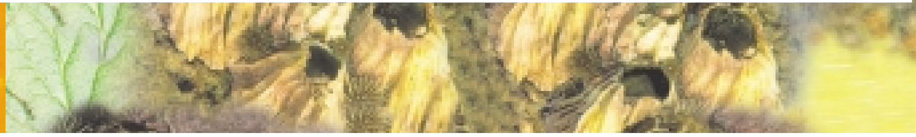
Biological Diversity

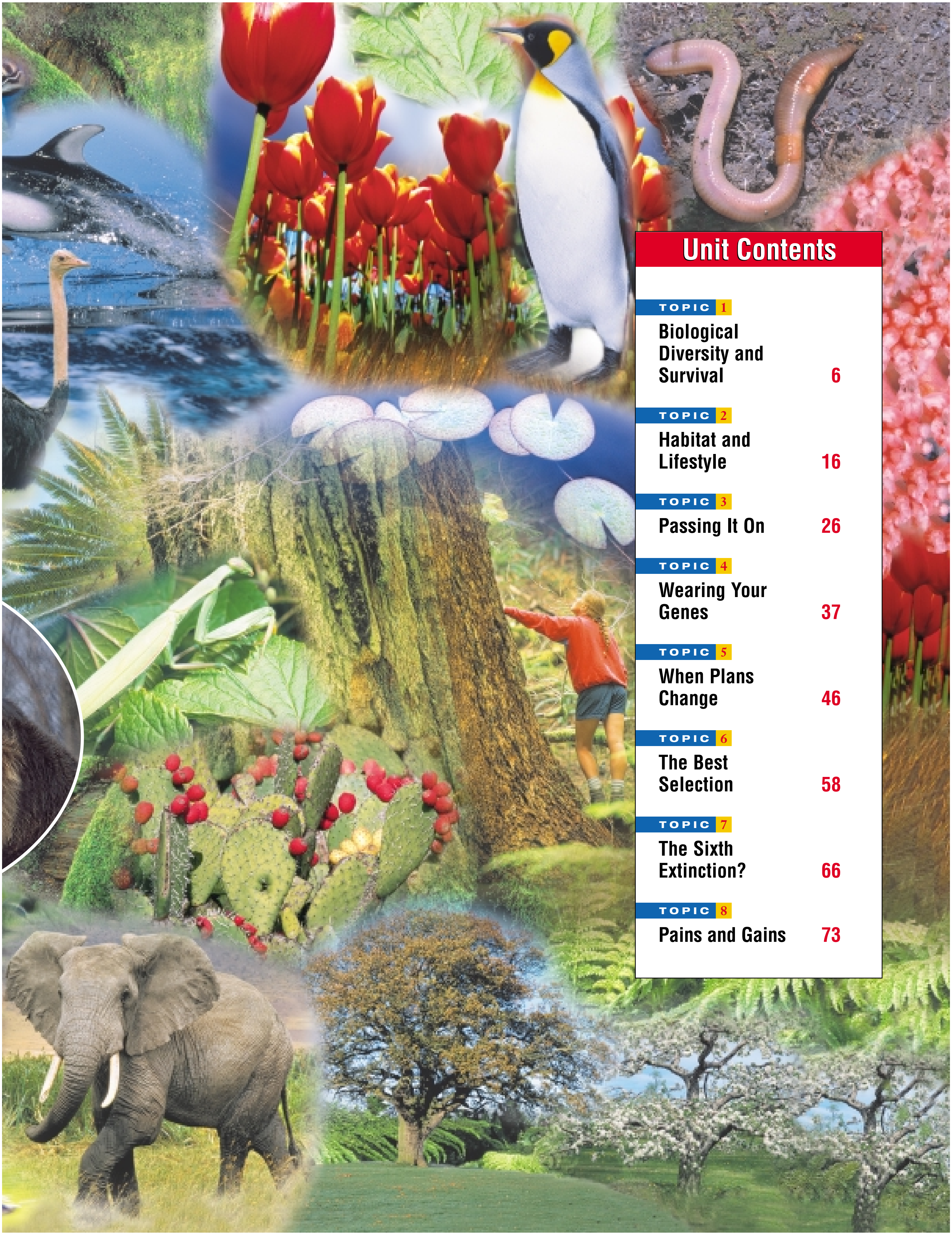
How would you feel if the grizzly bear pictured here were the last one left on Earth? Would it matter? Never before, since life appeared on this planet 3.5 billion years ago, have so many different species lived on the planet at the same time. From the simplest of cells to today's plants and animals, life has flourished and continues to express itself in amazing ways. E.O. Wilson, a famous U.S. biologist, has said that future generations may be able to forgive us for such disasters as using up Earth's stored energy supplies or destroying the economy. As terrible as these disasters would be, the environment could repair itself. Our one unforgivable act would be to contribute to the loss of Earth's biological diversity. This incredible variety of life that inhabits the world with us took millions of years to develop. Any losses could be permanent.

Biologists estimate the number of different plants, animals, and micro-organisms at about 15 million, but the number could be as high as 100 million. However, many species are at risk and the rate of extinction is increasing. What has caused this rate to increase? What can science teach us about the causes of extinctions and the importance of biological diversity?

In this unit you will:

- Learn about the diversity of life on Earth.
- Discover how living things pass on their traits to future generations.
- Investigate the impacts of human activities on biological diversity, and understand issues and decisions associated with future activities.





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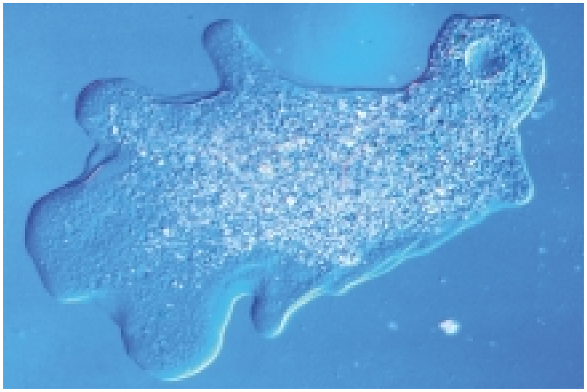
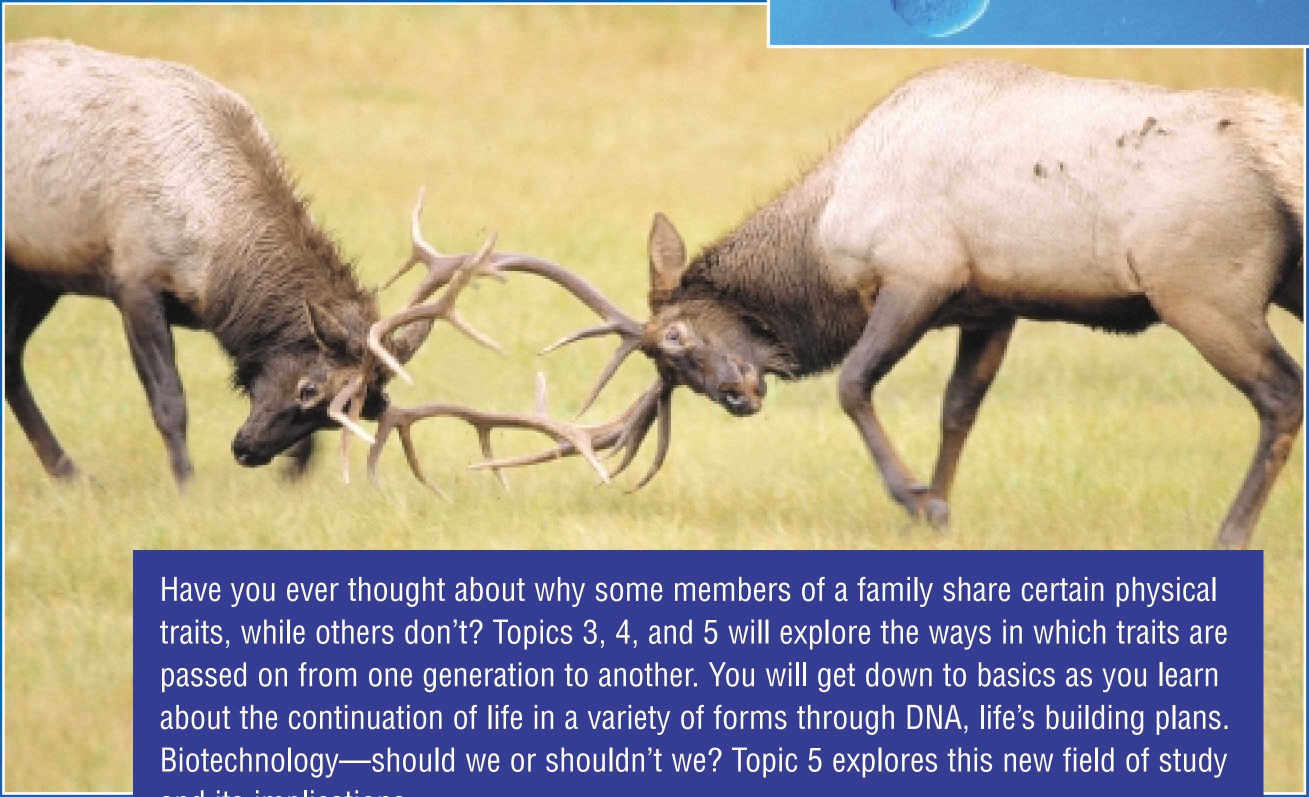
UNIT 1 Preview

Focussing Questions

- What does biological diversity look like?
- How do organisms pass on their traits?
- How can we prevent the loss of biological diversity on Earth?

What could a single-celled amoeba and a towering Douglas fir tree possibly have in common? You'll find some answers to this question in Topic 1 as you explore life's diversity. You will see what makes life forms similar and what makes them different. You will also investigate the special features that allow some organisms to succeed and survive, while others do not. What role do organisms play in their habitats? What are their relationships with other organisms? Read Topic 2 to find out.





Have you ever thought about why some members of a family share certain physical traits, while others don't? Topics 3, 4, and 5 will explore the ways in which traits are passed on from one generation to another. You will get down to basics as you learn about the continuation of life in a variety of forms through DNA, life's building plans. Biotechnology—should we or shouldn't we? Topic 5 explores this new field of study and its implications.

How does your lifestyle affect biological diversity? Topics 6, 7, and 8 provide an opportunity to examine changes in organisms and our influences on these changes. What do we need to know about other organisms in order to make decisions that will positively affect them?

Looking Ahead

Read pages 82–83. "An Issue to Analyze: To Burn or Not to Burn?" As a class, you will be assigned to investigate whether to use controlled fires in protected areas. You can begin by collecting information about controlled fires, forest fires, and protected natural spaces.

- Check newspapers for related articles.
- Look for information on this topic on the Internet.
- Speak with natural resources managers and scientists.
- Keep a file of the pros and cons, and decide what scientific background you need in order to make an effective decision.

TOPIC 1

Biological Diversity and Survival

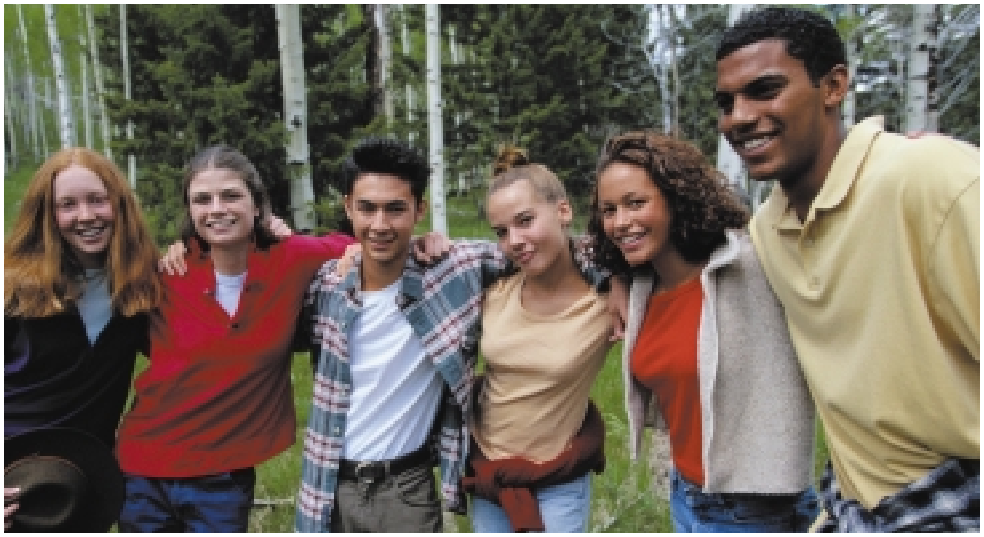


Figure 1.1 People, like all other life forms, display a wide variety of similarities and differences. What is it that makes us the same? What is it that makes us different?

No two people are alike. Look around your classroom. You recognize your friends because they have distinctive characteristics or features that make them different from everyone else. These differences or **variations** are a normal part of our lives. Variations are found not only in humans, but in all populations or groups of similar living things. The number and variety of organisms is called **biological diversity**. Why, and in what ways, might biological diversity be important?

Word CONNECT

You will often see the words "biological diversity" shortened to "biodiversity." This word is known as a portmanteau word, which means it is formed by merging the meaning of two different words. Where did the term "portmanteau word" come from? Look up "portmanteau" in the dictionary and write an explanation in your notebook. Write down two other examples of portmanteau words that you know.

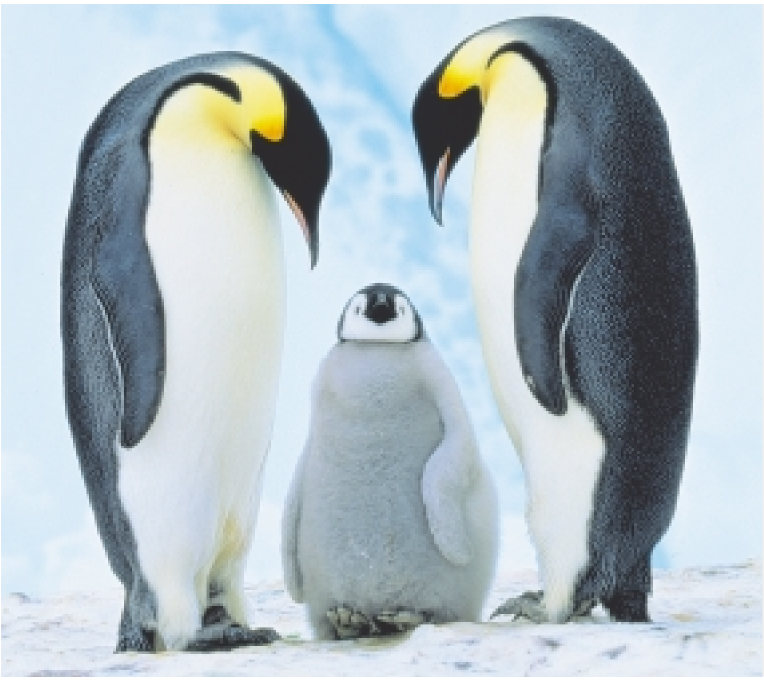


Figure 1.2 Can you see the variation among the individuals in the photograph above?

A Wealth of Diversity

Imagine a world without mosquitoes. That would be a good thing, wouldn't it – or would it? Besides the advantage of never suffering from another itchy mosquito bite, what other effects might there be? What would you need to know about mosquitoes in order to decide whether or not to try to eliminate them? How does the decision to eliminate one type of organism affect us and other species in both positive and negative ways? While people benefit from a wealth of biological diversity, so do entire ecosystems. What would happen to the food web if there were no more mosquitoes? Is there any way to predict the outcome?

As well, a great deal of our medicines come from biological sources. The Pacific yew tree, for example, is the source of a cancer-fighting chemical called Taxol. Before the discovery of Taxol, many people considered the Pacific yew a useless "trash" tree. Each time Earth loses a plant or animal species, are we also losing an important medicine?

Pause& Reflect

Make a note in your Science Log describing what might happen if a mosquito-eating bird were introduced to Alberta from another part of the world.

DidYouKnow?

Conserving venomous animals may be good for our health! How? Venoms are complex mixtures of compounds, with various effects. For instance, some snake venoms and secretions from frogs have antibacterial action. Such venoms could be the source of new antibiotics.

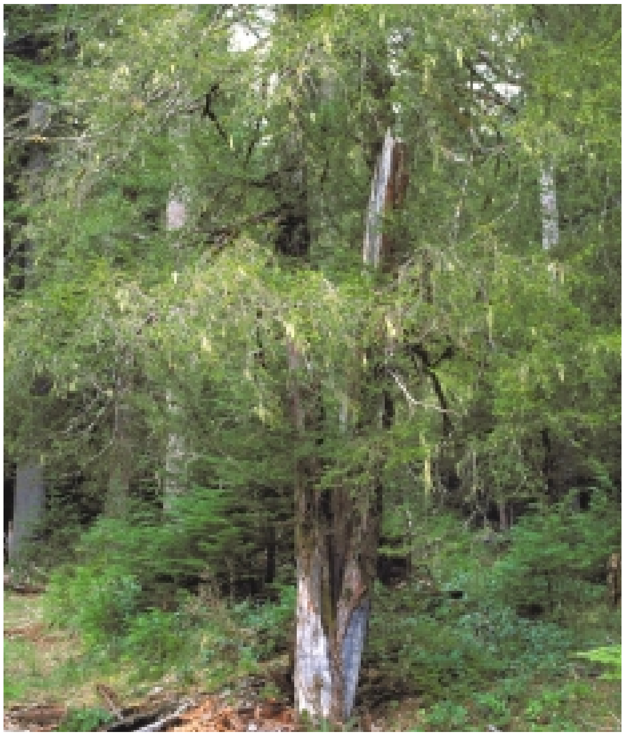


Figure 1.3 The Pacific yew tree was once burned as trash. Now, the tree is highly valued for its life-giving properties. Should we burn trees that cannot be used for building materials or other products? What would be the overall result of this action?

Scientists still have a lot to learn about how the different members in natural communities affect one another. Some studies suggest that when several different types of plants grow in an area, the interactions among them promote their growth. This research supports the belief of many scientists that biological diversity is important for the health and survival of natural communities.

Skill FOCUS

For tips on societal decision making turn to Skill Focus 8.

Pause& Reflect

In the 1700s Swedish biologist Carolus Linnaeus developed the system of naming species that we use today. His published lists of all species known to science included the names of over 4000 plants and 7000 animals. Since that time his list has expanded to include the names of over 1.75 million species. This listing is still incomplete! Some scientists believe we may have identified only 1–2% of the total number of species alive today. How will we maintain this diversity of life without even knowing some species exist? Write your thoughts in your Science Log. To review classification systems, turn to Appendix A.

DidYouKnow?

Organisms are often grouped together as a species if:

1. They interbreed in nature.
2. Their offspring are able to breed.

Tigers and lions are separate species. They are not known to breed together in the wild. Tigers and lions have been bred together in zoos, but their offspring are infertile.

Word CONNECT

The word "flora" refers to all of the plant life in a region. What do you think "fauna" means? Check the dictionary to see if you are correct.

Variation Within Species

Take a look at the photographs on the first page of this unit. Each organism is an example of a different **species**, or one type of plant or animal. In general, organisms of the same species are similar in appearance. However, there is always variation within a species.

To many of us all dandelions look the same. If you were to take a closer look, you would see differences between individual dandelion plants. In some cases biologists can have difficulty deciding if two similar groups of organisms belong to the same species. On the other hand, there can sometimes be a great deal of variation within a species.

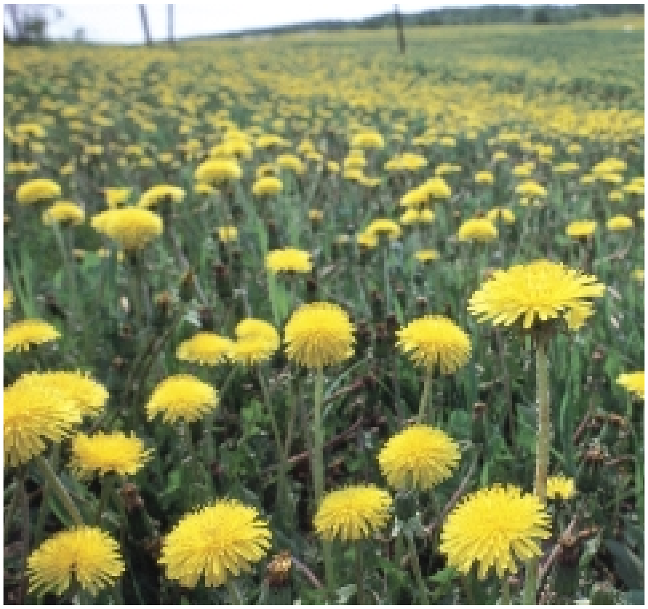


Figure 1.4 How many different species of dandelion are in this field?

Find Out ACTIVITY

Exploring Variation

All domestic cats belong to one species, *Felis catus*. However, these cats show many variations.

Materials

photographs of farm, house, or stray cats

Procedure

1. Along with your classmates, find a photograph of a domestic cat. You can look in magazines or newspapers, or you can use a photograph of your own pet.
2. Post the photographs (or photocopies) on a bulletin board in your class. Group the photographs of similar looking cats together.

What Did You Find Out? Analyzing and Interpreting

1. What are the major characteristics for each group of cats in the photographs?
2. How do purebreds differ from other domestic cats?
3. **Thinking Critically** Explain how the different types of cats might be suited to different environments.
4. **Thinking Critically** Which cats are most likely to be rat-hunters? Which cats are most likely to hunt mice?

Find Out **ACTIVITY**

A Classroom of Differences

Your school provides an excellent place to investigate variations or differences within a group of similar living things. In this case, the population consists of the students in your class and the variations are physical characteristics that you can easily measure.

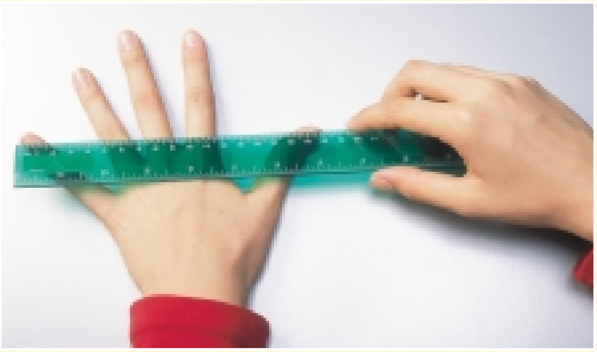
Materials

tape measure	chalk and pencils
chalkboard	flipchart paper

Procedure

Performing and Recording
Communication and Teamwork

1. Working in pairs, measure each student's height to the nearest centimetre and record each measurement on the chalkboard.
2. Stretch out your hand. Measure the distance (to the nearest millimetre) from the tip of the thumb to the tip of the little finger of your outstretched hand. Again record all results on the chalkboard.



Skill FOCUS

For tips on how to prepare graphs, turn to Skill Focus 10.

3. Measure, or have your partner measure, the distance around your left wrist to the nearest millimetre at the point where the wrist bone sticks up. Record your results on the chalkboard.

4. Write all of the class results in your notebook and record the class results for each set of measurements on the chalkboard or separate pieces of flipchart paper. Show each measurement and the number of students that share it. Put the measurements into groups. For example, put the number of students that have heights between 176–180 cm into one group.
5. Prepare a histogram for each of your three measurements. You may use a computer to record and sort the data and draw the graphs.

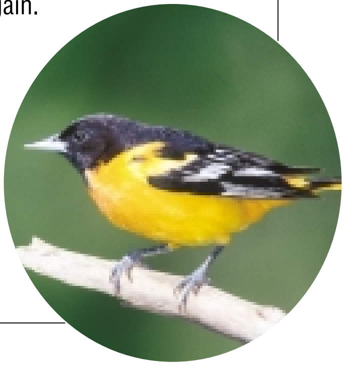
What Did You Find Out?

Analyzing and Interpreting

1. Are there any similarities between the graphs?
2. Can you explain the shapes of the graphs?
3. Is there any reason why a graph for right wrist measurements might be different from left wrist measurements?
4. What are some of the factors that might cause variations between you and your classmates?

Did You Know?

Taxonomists classify things, such as living organisms. Sometimes taxonomists have lengthy discussions about whether or not two organisms belong to the same species. For example, Bullock's and Baltimore orioles were once considered separate species. Later, the birds were re-classified as a single species, the northern oriole. Recently, scientists split the grouping once again. Why might it be important to know whether or not two types of organisms belonged to the same species?

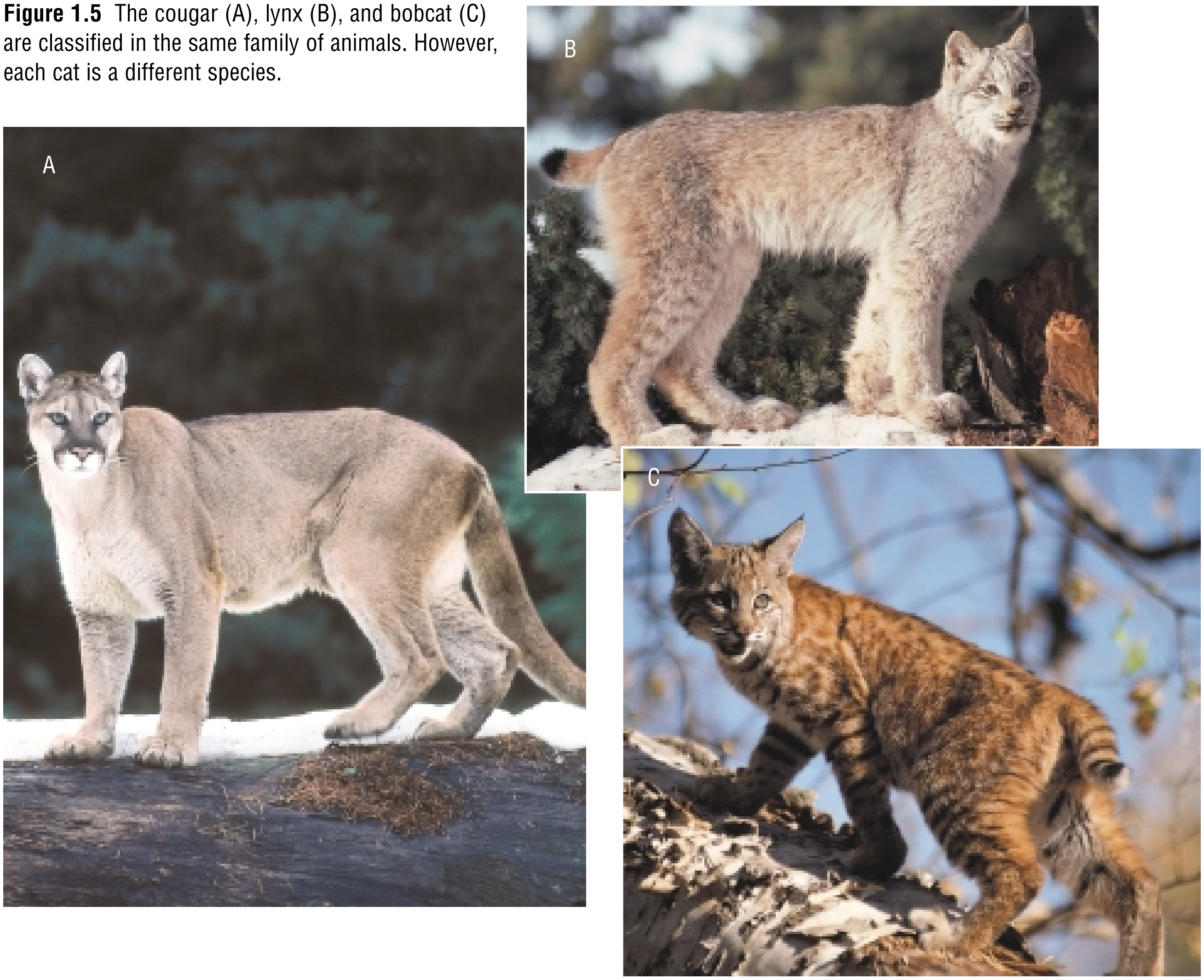


Variation Among Species

Many organisms show similar characteristics: insects have six legs, birds have feathers, and mammals nurse their young. Even so, there are many species of each of these creatures. How did so much variety come about? To answer this question scientists have looked to areas of the world that are rich in various species of plants and animals. Great biological diversity often occurs on islands, or other places where animals and plants have been isolated for a long time.

Many studies on similar species, such as wild cats like the lynx, bobcat, and cougar, indicate that all came from a common ancestor. Over time, one type of cat evolved into a variety of similar yet separate species. This process is called **speciation**. Much of Earth's biological diversity is due to speciation.

Figure 1.5 The cougar (A), lynx (B), and bobcat (C) are classified in the same family of animals. However, each cat is a different species.



THINK & LINK

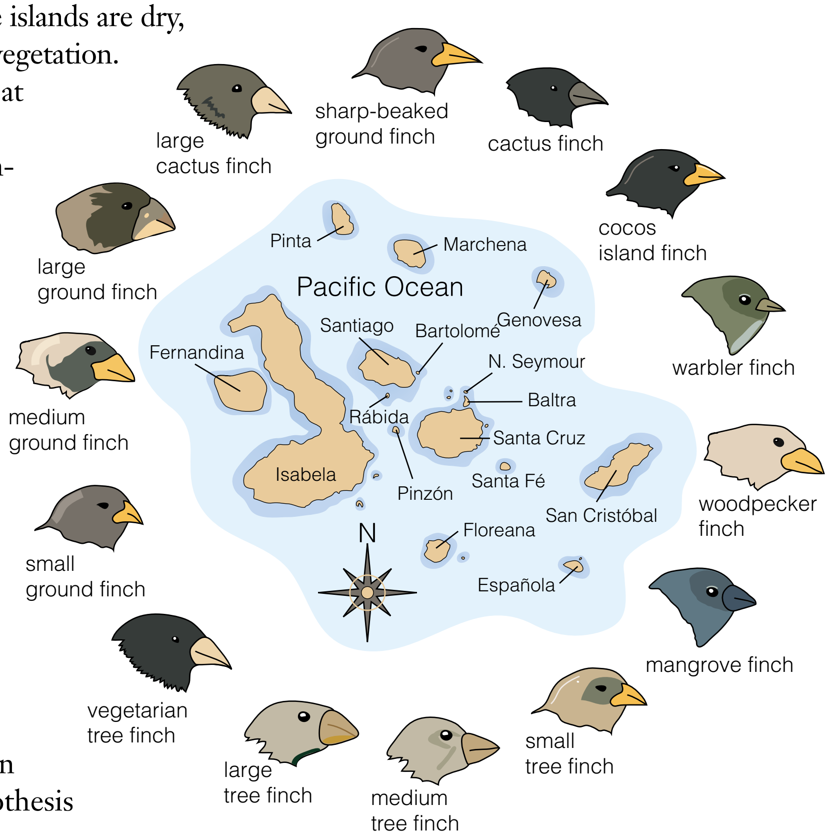
INVESTIGATION 1-A

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- Communication and Teamwork

The Galápagos Finches

Think About It

The Galápagos Islands are located on the Equator in the Pacific Ocean about 1000 km from the coast of Ecuador, South America. The 13 main islands and several smaller islands are volcanic in origin and contain a number of ecosystems. At lower elevations the islands are dry, and bushes, trees, and cacti make up the vegetation. Humid forests grow on the larger islands at higher elevations. On his stop at the Galápagos, biologist Charles Darwin gathered specimens of birds from some of the islands. He noticed that there were a large number of closely related finches, each of which was a distinctive species. Darwin counted 13 species of finch from the Galápagos, and one from Cocos Island, located 830 km north of the Galápagos. In this investigation you will examine Darwin's finches and how the islands gave rise to the variety of different species.



What To Do

❶ Study the diagram of the different finches. What is the major anatomical difference between the species illustrated? Form a hypothesis that might explain the difference between, for example, the woodpecker finch and the cactus finch.

❷ Ground finches that depend primarily on seeds as a source of food live primarily on solidified lava beds. What kinds of habitats might be suitable for some other species of finches? If information is available, match these habitats to particular islands.

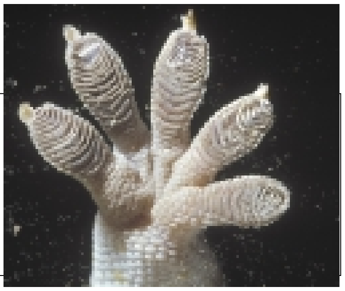
❸ Research the different areas on the Galápagos Islands. What are the conditions like in each of these places?

Analyze

1. Did your research findings support your hypothesis?
2. What problems might you encounter when developing a hypothesis from an artist's drawing of an organism?

Off the Wall

Geckos are small lizards with some strange habits! They can walk upside down across the bottom of a leaf without falling off. As they walk, their feet uncurl, flattening tiny projections called setae. Intermolecular forces of attraction bond the setae to the leaf's surface.



INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Madagascar is an island that lies off the coast of Africa. The unique species on Madagascar attract biologists from around the world. Unfortunately, many of these species are endangered. Choose one species from Madagascar and find out what makes it one of a kind. What effect would the loss of this species have on other species in Madagascar? Create a poster by hand or on a computer that shows this plant or animal's special features. To begin your research, go to the web site above, and click on Web Links to find out where to go next.

Variations for Survival

As you may remember, every organism has adaptations that enable it to survive in its environment. There are many ways to solve a problem, such as obtaining food. As a result, a great variety of adaptations can be seen in living things. Examine the photographs shown below. Most plants obtain nutrients through their roots. The pitcher plant has an unusual way of obtaining the nutrient nitrogen. This plant obtains nitrogen from insects that it traps in its pitcher shaped leaf. This physical feature is a **structural adaptation**. **Behavioural adaptations** include the owl hunting at night and the migration of birds from the tropics to their nesting sites in the Far North. Variation in animal behaviours is not only interesting, but as you will learn in Topic 2, different behavioural adaptations allow each species to have its own place in an ecosystem.

***Math* CONNECT**

The rufous hummingbird migrates farther than any bird its size. Each year rufous hummingbirds migrate from Mexico or the southern United States to summer homes in the northwestern states and western Canada, including southwestern Alberta. If a rufous hummingbird travels 1800 km, it will travel a distance 2×10^7 times the length of its body. How big is the rufous hummingbird? Give your answer in centimetres.

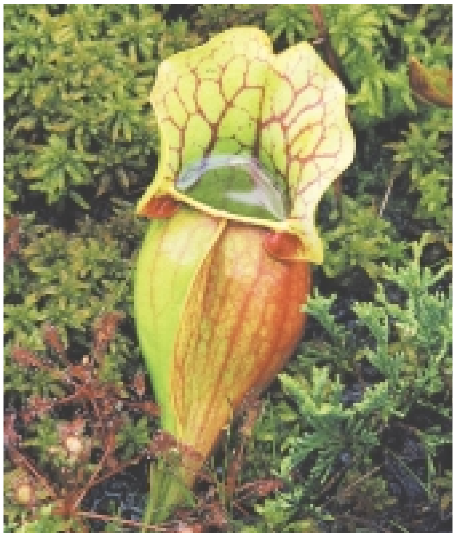


Figure 1.6 The pitcher plant may be found in boggy areas of northeastern Alberta and near Edson, typically in nitrogen-poor soils. Insects that are attracted to the plant slip down the smooth lip of the leaf into a liquid at the base. There they drown and are digested by the plant.

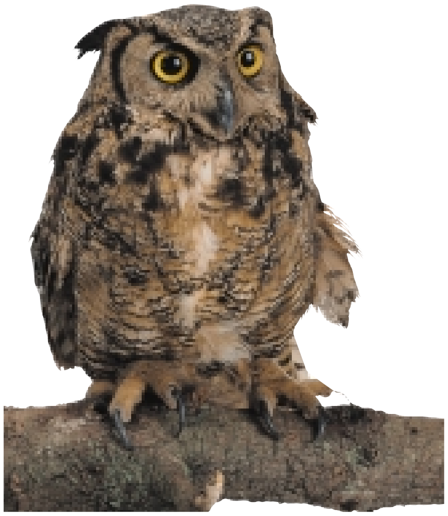


Figure 1.7 Most owls are nocturnal. This behavioural adaptation goes along with certain structural adaptations. What might some of these structural adaptations be? How do nocturnal owls differ from birds such as magpies that feed during the day?

The Value of Variation

Western forests are under attack. The mountain pine beetle is a pest of the lodgepole pine, a very common tree in the Rocky Mountains. A mountain pine beetle infestation can destroy a forest that is made up mainly of lodgepole pine. In contrast, areas with greater biological diversity are often more able to tolerate changes in the environment. A forest with many tree species has a good chance of staying healthy in spite of disease. If a disease destroys only one species of tree, the other trees will remain unharmed.

The lodgepole pine is an important source of timber in Canada. Finding a lasting solution to the mountain pine beetle problem could have economic benefits. Mature lodgepole pine are less resistant to infection, so one solution is to burn areas with older trees. What information would help you decide if burning these trees would be the best action to take?

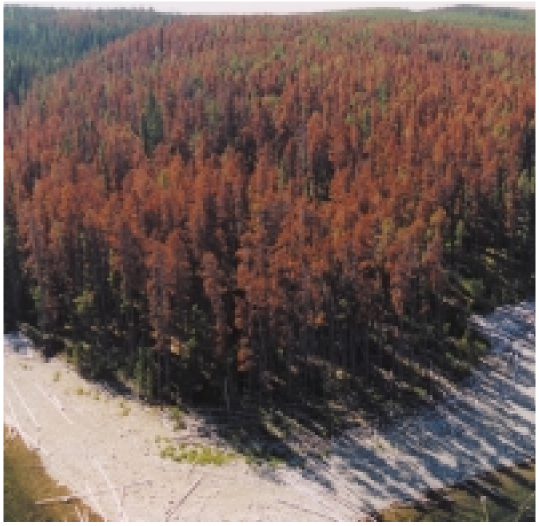


Figure 1.8 This forest has been hit by a mountain pine beetle infestation. The beetle bores into the bark, carrying the spores of the bluestain fungus with it. Fungal infection and damage caused by the beetles eventually kill the trees.

Measuring Biological Diversity

EXTENSION

To determine the biological diversity of an area, biologists use a measurement called the **diversity index**. This measurement compares the diversity of species in an area with the total number of organisms in the same area. It is normal for some places to have a higher diversity index than others.

The diversity index can be used to check the health of an ecosystem. For example, a river with many different kinds of organisms living in it would have a high diversity index. The river would also likely be healthier than a river that supports only a few types of organisms. Why would this be true? In fact, the large number of different species in a healthy river prevents the population of any one type of organism from becoming too great. A polluted river may have large numbers of the same organism. However, this river would support only the few species that are able to live in polluted conditions. You may remember that when rivers become polluted with sewage, algae can grow out of control, killing off other species. Such a river would have a low diversity index.

Did You Know?

The influenza outbreak of 1918–1919 killed 50 000 people in Canada alone. In just one year, the pandemic (a global outbreak) killed 25 million people worldwide. Yet 18 months after the disease was reported, it disappeared. It now seems that the virus ran out of susceptible people. Whether or not someone is likely to catch a disease can depend on the person's age, genetics, or general health. The fact that some people get diseases and others do not is another example of variation. Even today, scientists are only beginning to understand why some people get sick and others do not.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Why is there a new flu virus every year? It turns out that the flu virus is a master at variation! To learn more about the flu virus, visit the above web site. Go to the web site above, and click on Web Links to find out where to go next. Write a paragraph that explains why the human body has trouble recognizing the flu virus. Build a model of the flu virus using modelling clay or create a computer model using modelling software to help illustrate your answer.

Looking Ahead

Remember to keep planning for your Unit 1 Issue Analysis. Think about the forum as you work through each Topic in this unit.

INQUIRY

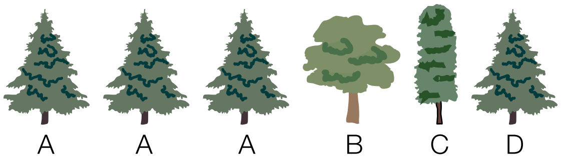
INVESTIGATION 1-B

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Using the Diversity Index

In this investigation you will begin to explore the biodiversity of an area by focussing on one small piece of it. You will focus in even further by studying tree diversity only and developing a tree diversity index.



Question

How can the diversity index be used to measure diversity in different areas?

Hypothesis

State a hypothesis about the diversity of trees in natural areas compared to areas of human activity. Predict which of the areas in your study will have a higher tree diversity index.

Apparatus

notebook	pen
ball of string	metre sticks

Procedure

① Working in a group, **decide** upon two different study areas. One should be an area of human activity (such as a school yard or street) and the other a natural area (such as a community park).

② Using a string line 25 m in length, measure a path in the area you have chosen to study. Imagine a carpet that extends out one metre on either side of your string line. Beginning at one end of the string line, start to count all of the trees with a trunk that is inside or at least touches your two metre-wide carpet. (You might want to use your metre stick to measure in a case where you're unsure whether a tree is inside or outside the area.)

③ **Record** the first tree in the area as "A." If the next tree is the same as the first, **record** it as another "A." If the second tree is different from the first, **record** it as "B." Every time you come across a tree that is different from the last one, **record** a new letter (C, D, etc.). It is the change from one kind of tree to another that indicates diversity. Each change starts a new "run" of data. (See the example above.)

④ **Determine** the number of runs in your trial by counting how many different letters you have recorded. There were four runs in total in the example provided (AAABCD).

⑤ **Count** the total number of specimens (trees) in your trial. In the example trial there were six specimens.

⑦ Copy the data table below in your notebook. Complete the table.

Data Table
Number of Runs =
Number of Specimens =
Diversity Index = $\frac{\text{Number of Runs}}{\text{Number of Specimens}}$ =

⑦ Repeat steps 2–5 for the second study area.

Analyze

1. Which area has a higher tree diversity index?

2. How did your results compare with those of other groups in the class?

Conclude and Apply

3. The closer the diversity index is to one, the more diversity there is within an ecosystem. The smaller the diversity index, the less diversity there is in an area. Which of your two sites had more tree diversity?

4. Did your observations support your hypothesis? How could you design an investigation to test for variables that might affect tree diversity in different areas?

Career CONNECT

The Nature of the Job

Imagine spending your working day walking along quiet woodland trails. Interpretive naturalists do just this! They lead nature walks and explain the natural environment to others, from young children to adults. Most naturalists work at conservation areas, wildlife reserves, government parks, or for conservation groups. Through nature walks, they help visitors experience nature first-hand. Naturalists also give talks, prepare displays, and sometimes write informational leaflets. They may even take care of animals or help maintain the habitats of local wildlife.

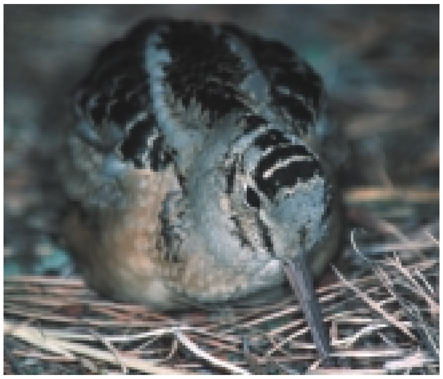
In this job, a love of both the outdoors and working with people is essential. Most interpretive naturalists are good communicators and have a post-secondary science degree. This may be either a Bachelor of Science degree from a university, or a college degree in outdoor education, wildlife studies, ecology, wildlife biology, or a related subject.

Can you picture yourself as an interpretive naturalist? Make two lists: one listing the parts of this job that appeal to you, and the other listing the parts that do not. Then complete the statement below using as many points as possible that apply to you. Your points can be as simple as “will not have to wear business clothes” or “can travel.” Choose five points that you feel will be the most important to you when choosing a career.

I am interested in a career in which I . . .

TOPIC 1 Review

1. Write your own definition for biological diversity.
2. Think about a time you have seen a flock of Canada geese (*Branta canadensis*) flying overhead. If you could examine the geese closely, would they look identical? Explain your answer.
3. **Apply** Name a situation in which it would be useful to determine the diversity index of an area.
4. **Thinking Critically** Invent an animal that is perfectly adapted for living inside the school gym.
5. One variation seen in birds is the placement of the eyes. Shown here is the American woodcock, which feeds on worms in the ground. Its eyes are located virtually on the top of the head. Explain how this variation may be a useful adaptation.

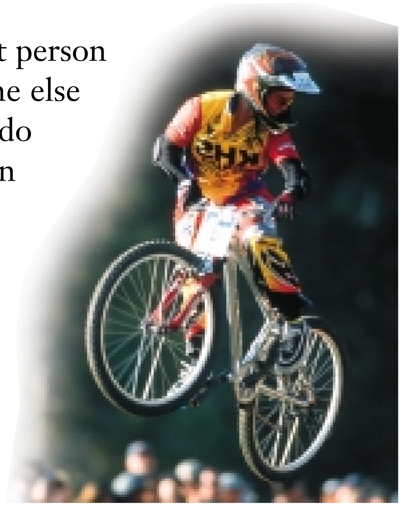


6. The bubonic plague, or Black Death, kills people every year. However, it was devastating when it swept through Europe in the sixth, fourteenth, and seventeenth centuries. It killed 90% of the people exposed to the germ and resulted in the deaths of approximately 137 million people. Why was everyone not killed by the Black Death?

Pause & Reflect

Biologists can use diversity indexes to monitor the health of Alberta ecosystems. What types of human activities could lower the diversity index of grasslands? How would you decide if these activities should be continued? Write your ideas in your Science Log

TOPIC 2 Habitat and Lifestyle



Everyone has special talents that make that person unique. What do you do better than anyone else in the class? Like people, some organisms do some things better than others. Variation in people and other organisms is more than just physical appearance. It can also be what an organism does well. For example, dandelions grow well in bright sunlight, while ferns grow well in the shade.

The Niche: What Makes an Organism Special?

As you have seen, adaptations allow an organism to play a specific role in its environment. Adaptations also help organisms to compete with each other for the needs of life. You may remember from earlier studies that an organism's niche includes two parts: where an organism lives (its habitat) and what it does. Look at the poplar tree in Figure 1.9. This poplar's habitat is a mountain forest just outside of Banff. But what does the poplar tree do? What is its role?

Pause& Reflect

Describe the niches of three other organisms found in Alberta. Describe at least one plant and one animal. Write your answers in your Science Log.

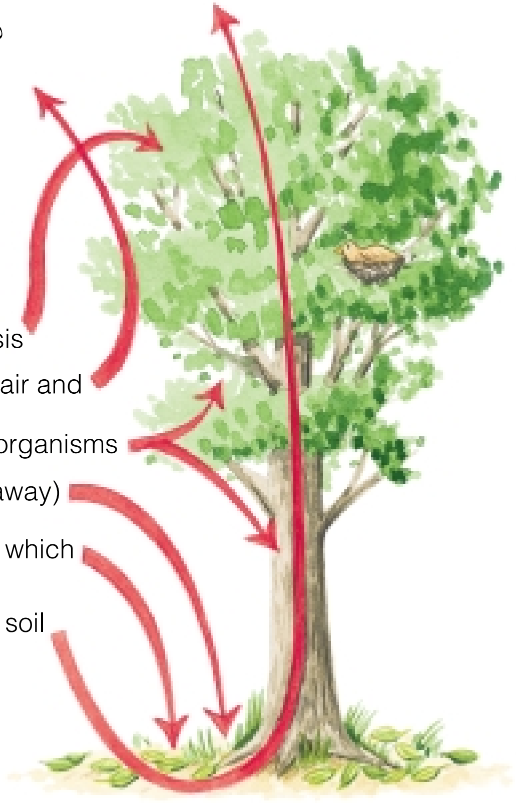

A poplar tree:
absorbs light for photosynthesis
removes carbon dioxide from the air and releases oxygen into the air
provides food and shelter for a wide variety of organisms
stabilizes the soil from erosion (wearing away)
covers the ground with leaves in the fall, which returns nutrients back into the soil
removes water and nutrients from the soil

Figure 1.9 This poplar tree performs many functions, which, together with its habitat, make up its niche.

These various activities are what the poplar tree "does" and they make up its role in the ecosystem.

Variation and Competition

When resources such as food, water, or sunlight are plentiful, many species can share them. However, when any one of these resources becomes scarce, the organisms that depend on the resource must compete for it. **Competition** can occur between members of the same species or between different species.

Whenever two individuals compete, variations between the individuals may give one of them an advantage. Again, this is true of members of the same or different species. For example, if two species, such as mule deer and white-tailed deer, are competing for the same resource, one may have more favourable adaptations. Mule deer are able to tolerate cold winters much better than white-tailed deer. However, white-tailed deer thrive near agricultural lands. Depending on the surroundings, the members of one species may be faster or better able to avoid predators. This would allow the better-adapted deer species to reproduce and eventually "take over." In order for future generations to survive, the less successful species may have to change to a less desirable food source or move to another habitat.

Did You Know?

Hawaiian plants do not have thorns or toxins. Although pigs, goats, and deer have been introduced to the islands, there are no browsing mammals native to Hawaii. As a result, native plants did not evolve adaptations for protection from browsing mammals.

Figure 1.10 These deer must compete with each other and with other species for food and space.

Some species avoid competition with more dominant species by using a different food source or keeping different habits or behaviours. Cougar hunt large herbivores like deer, elk, or bighorn sheep, and are usually found in thick pine forests. Lynx can inhabit the same area as cougars, but tend to feed on snowshoe hare. Many owls avoid competing with hawks by hunting at night. As organisms change to avoid or reduce competition, they alter their niches. These subtle changes eventually increase the variation within or between species.

Looking Ahead

Think about what you would need to know about various species of trees and other plants in order to discuss the issue on pages 82–83. Is there an advantage to removing old trees? What effect might this action have on competition among other kinds of organisms on the area?

Warblers are small, active birds with sharp beaks adapted for capturing insects. Numerous species of warblers can be found in Alberta during the summer. They winter in the southern United States and in Central and South America. In the spruce forests of Canada five warbler species can co-exist in the same tree:

- Cape May warbler feeds on insects at the top and tips of the tree.
- Yellow-rumped warbler feeds on insects near the trunk's lower branches and on the ground.
- Black-throated green warbler feeds near the middle of the tree.
- Blackburnian warbler feeds from the outer tips from the middle to the top.
- Bay-breasted warbler feeds from the lower half of the tree away from the tips.

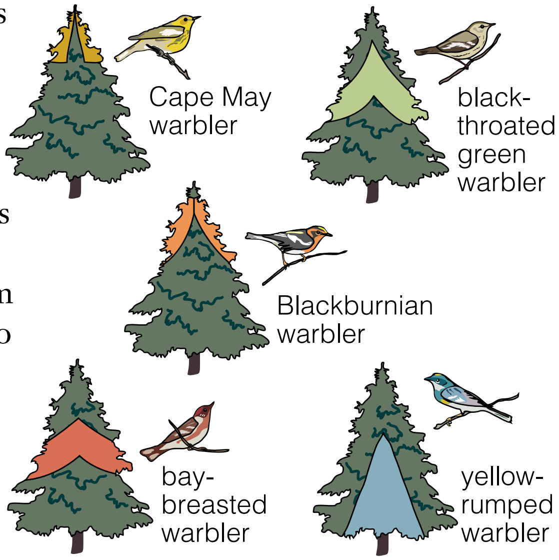


Figure 1.11 Which characteristics do all of the warblers share? How are these birds able to avoid competing with one another?

All of these birds live in the same tree, but do they share the same niche?

Animals are not the only organisms that have very specific niches. Did you know that countless numbers of micro-organisms inhabit the human body? You could say that each part of your body is its own ecosystem. Most of these micro-organisms are not harmful and the different species that inhabit the skin, the mouth, and the digestive tract are your constant companions.

Pause& Reflect

In your Science Log, create a scenario that would explain how the feeding habits of the different warblers developed.

Pause& Reflect

Explain why the diagram of the spruce tree does not show a completely accurate picture of the warblers' feeding patterns. How could you design an experiment to get a more accurate picture of what is happening? Write your thoughts in your Science Log.

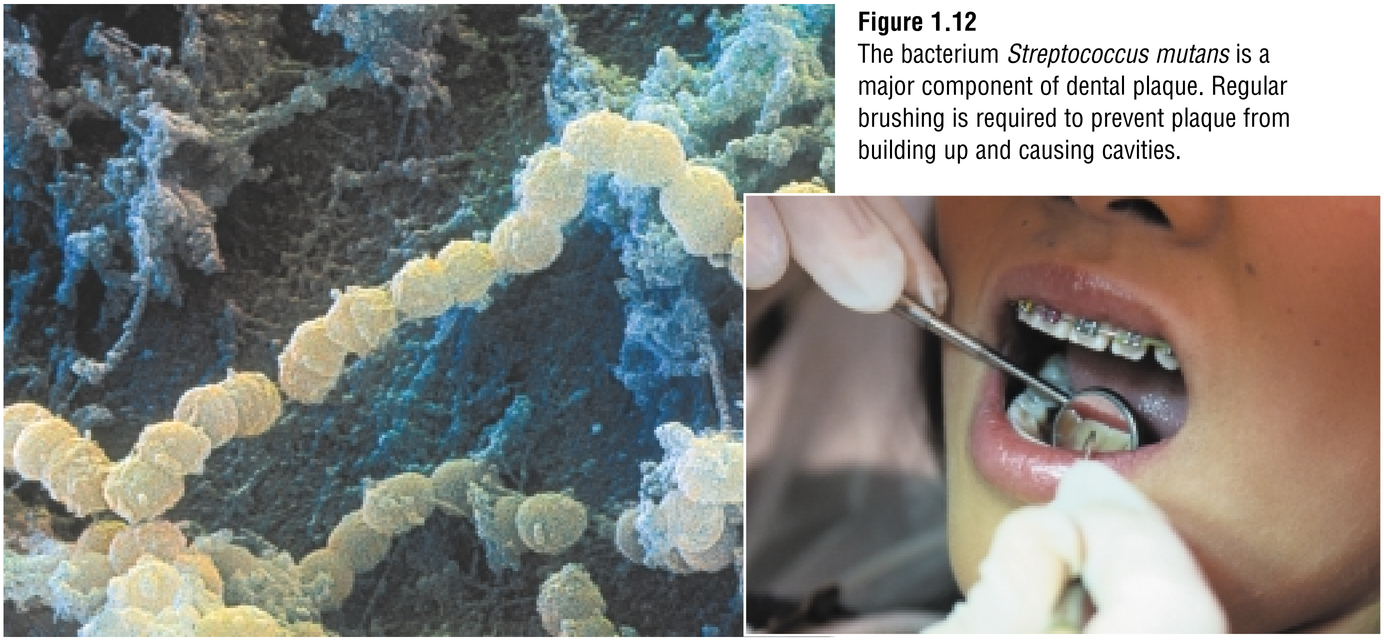


Figure 1.12
The bacterium *Streptococcus mutans* is a major component of dental plaque. Regular brushing is required to prevent plaque from building up and causing cavities.

Find Out **ACTIVITY**

Bird Watching

Alberta is home to many birds, such as the robin, sparrow, magpie, chickadee, and duck, which are common in neighbourhood backyards or parks.

Materials

binoculars (optional)
tape recorder (optional)
notebook
pens

Procedure

- Initiating and Planning
- Communication and Teamwork
- Performing and Recording

1. With a group, choose two or three birds in your neighbourhood to observe. Devise a procedure for making and recording observations.
2. Make your observations of the birds, keeping the following questions in mind:
   - **(a)** In what location do the birds live? (For example, one bird may live next to a pond in the local park.)
   - **(b)** Where do the birds make their nests?
   - **(c)** What do the birds eat?
   - **(d)** Do other birds or animals live in the same area as the birds you are studying? Which ones?

What Did You Find Out?

- Analyzing and Interpreting

1. How were your answers similar to or different from your classmates' answers?
2. Based on your observations, describe the niches of your study birds. Compare and contrast their niches.
3. How would your observations be different if you had done this activity at another time of year?

The Broad Niche

If you have had the chance to travel around northern Canada and observe the wildlife, you may have noticed two things. First, there are not as many different species of plants and animals as there are in other regions. Second, there are very large populations of the species that you do find. There are vast herds of caribou and millions of arctic hare. Even large carnivores like wolves and polar bears are found not only in northern Canada but also all around the northern regions of the globe. These same species of wolf *(Canis lupus)* and polar bear *(Ursus maritimus)* are found in Russia and northern Europe. In contrast, if you travel through the rainforests of Central and South America, you may see hundreds or thousands of different species, but each population is very small. It is quite possible that you could walk through the jungle and not see the same kind of bird twice in one day.

Figure 1.13 Wolves need large areas of land to live. Wolves currently travel between Canada and the United States along a wildlife corridor, a natural route used by animals, in the Rocky Mountain region.

Why do Canadian ecosystems lack diversity but support high numbers of the species that live here? The animals that live here year-round must be able to withstand daily and seasonal changes in temperature.

They also must be able to eat a variety of plants or other animals as seasons and conditions change. There are exceptions, but in general, organisms that survive here must have a **broad niche**. They must have adaptations that allow them to survive in the heat of the summer and the freezing cold of the winter. These Canadian species are **generalists** that are able to spread over large areas.

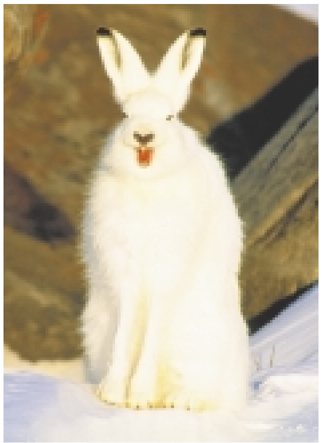


Figure 1.14 Like the caribou, polar bear, and wolf, the arctic hare is a generalist, and is adapted to living in cold winters and mild summers.

Pause& Reflect

Plants and animals that have specialized niches in wetlands are put at risk when wetlands are drained. Research Alberta wetlands to learn about some of the species that live there. You can use the library or the Internet for your research, or you can contact an expert with a wildlife conservation group. How would you advise the local government about any plans to build houses over a wetland area? Record your findings in your Science Log.

Diversity in the Tropics: The Dangers of a Narrow Niche

In the tropics, temperatures and food supplies are relatively stable. In these regions, most organisms are **specialists**, which means they have adaptations that make them very efficient at surviving in their own environments. Plants and animals tend to have very **narrow niches** with adaptations directed toward competing for one dependable food source, one type of soil, or one level of light. This **specialization** allows many different species to inhabit a single area, but it prevents any one species from spreading over a large area. The result is that the tropics have an incredible diversity of species, but their populations tend to remain low.

A specialist is well suited to one particular environment. This has been described as "the trap of specialization." As the species competes with others, the more useful adaptations it acquires and the more successful it becomes. However, many of the adaptations that make a species successful in one environment may prevent it from being able to inhabit other environments. For example, the lion-tailed macaque of India is specialized for life in the forest canopy. This monkey is not suited for life on the ground. As the forests are cut down the lion-tailed macaque has nowhere else to live.

Figure 1.15 The tropical rain forests of the world are areas of rich biological diversity. Many parts of these forests have never been explored by scientists and likely contain many undiscovered species.

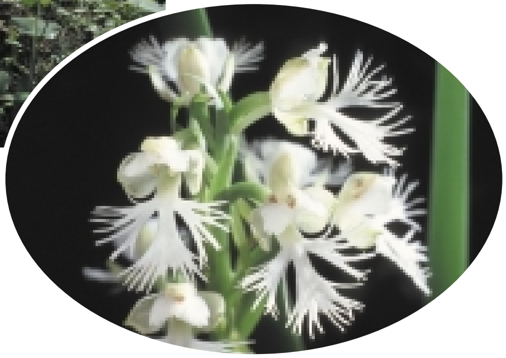


Figure 1.16 Not all specialists live in the tropics. The prairie white-fringed orchid is an endangered specialist. If populations of the hawkmoths that pollinate this flower decrease, what will happen to the orchid?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

What happens if a new species is introduced into a food web? To begin your research for this activity, go to the web site above, and click on Web Links to find out where to go next. Present your findings in a short talk to your class.

Find Out ACTIVITY

Introducing . . .

Generalists can live almost anywhere. Their adaptations allow them to survive in a variety of environments and live on a variety of different food sources. When introduced into a new area where there are too few predators or competing organisms, generalists spread rapidly. As you may recall, an introduced generalist can sometimes take over, forcing out species that are specialized for life in local ecosystems.

Procedure ✸ **Performing and Recording**

Research an example of an introduced species, find out if it was introduced intentionally or accidentally, and detail its effect on local species and ecosystems.

What Did You Find Out? ✸ **Analyzing and Interpreting**

1. How have populations of local species changed since the arrival of the introduced species?
2. What niche does the introduced species now occupy?
3. Should we limit the spread of the introduced species? If so, what steps are being taken to control the further spread of this species?
4. Make a list of all of the species introduced to Canada that you and your classmates have researched. Enter the names of these species into a data base that other people can search.

Dependencies Between Species

Living things have struggled to survive for millions of years. Few, if any, have done so alone. You may think that an elk needs only water to drink and plants to eat. In fact, the elk would not be able to digest its food without the help of communities of micro-organisms that live in the elk's rumen, a specialized stomach. In turn, the elk provides the micro-organisms with a place to live. This kind of close partnership is common in natural communities.

Many plants depend on mycorrhizae, specialized fungi, to help absorb water and minerals from the soil. The fungi attach to the roots of the plants, which increases the surface area of the roots. The mycorrhizae also protect the plants from some diseases. The fungus benefits by being able to draw nutrients from the plants. You may recognize that this is a **symbiotic** relationship in which two organisms live in direct contact. It is also an example of mutualism, because the relationship benefits both species.

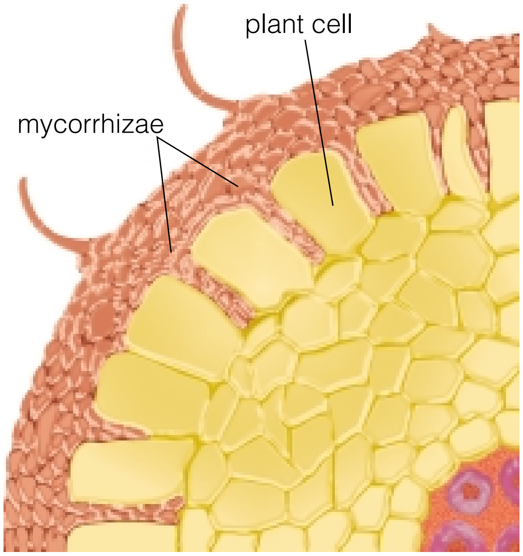


Figure 1.17 The ability of plants and mycorrhizae to live in symbiosis is an adaptation — but with a difference. In each case the adaptation was made in close harmony with the other species. Both partners in the relationship developed compatible adaptations at the same time. Here, the fungus is shown as it infects a plant root.

INTERNET CONNECT

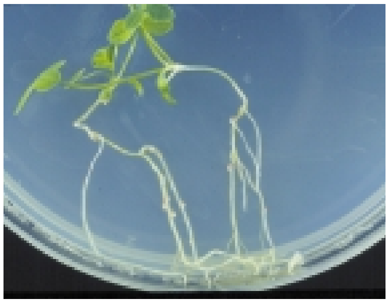
www.mcgrawhill.ca/links/sciencefocus9

Many micro-organisms play important roles in the environment. To find out more about them, go to the web site above, and click on Web Links to find out where to go next. Record the names of three or more beneficial micro-organisms. Write a short paragraph explaining the importance of each.

SKILLCHECK
- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- Communication and Teamwork

Clover and Soil Bacteria

Clover, peas, beans, and other plants called legumes have symbiotic relationships with certain soil bacteria. These bacteria, known as rhizobia, are able to live in the plant roots, where they remove nitrogen from the air and change it into nitrogen compounds the plant can use.



Hypothesis

Formulate a hypothesis about the importance of rhizobia to clover plants and their role in soil communities.

Safety Precautions

- Be careful when cutting nodules from roots.

Apparatus

small shovel
scissors
eye dropper
microscope
slide
cover slip

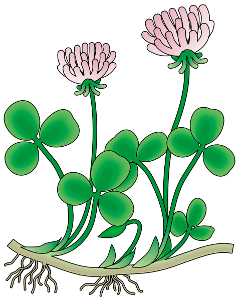
Materials

methylene blue dye

Procedure

① Clover is found in most lawns and fields. Find patches of clover in your schoolyard or local park.

② Dig up two or three clover plants, taking care to keep the roots intact.



③ In the lab, gently rinse the roots to remove any soil.

④ **Examine** the roots to find any bumps or nodules (see figure at top right).

⑤ Cut out one or two of the nodules and place them on a microscope slide. Add one or two drops of methylene blue dye. Put on a cover slip and press gently on the cover slip to crush the nodules.

⑦ **Observe** the nodules on the highest magnification available.

Analyze

1. Where did you find the clover?
2. Could you see the bacteria from the crushed nodule?
3. Why is it difficult to see the bacteria?

Conclude and Apply

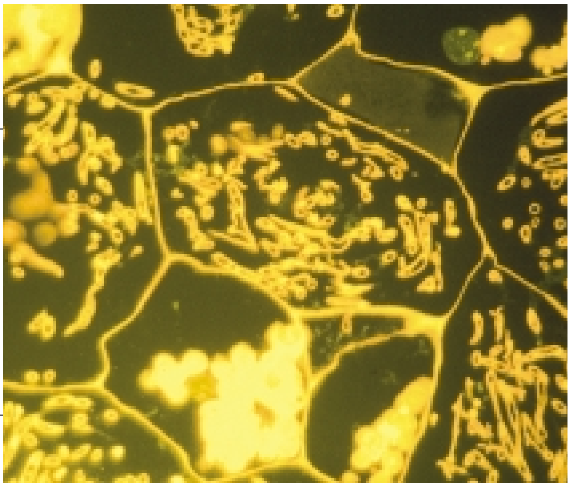
4. What evidence did you observe in the field that indicates the bacteria are adding nitrogen to the soil?
5. Why do farmers sometimes alternate clover with other crops?
6. Can legume plants grow without living in symbiosis with rhizobia? Explain your answer.

Extend Your Knowledge

7. Repeat the experiment with pea plants or bean plants. Choose plants from fertilized and unfertilized soils. Which plants have nodules? Explain your findings.

Cool Tools

Without special stains, many microscopic structures would be almost impossible to see, even using a microscope. As mycorrhizal fungi surround and enter roots, the roots themselves change shape. Shown here are the roots of an orchid seedling colonized by a mycorrhizal fungus. In order to see mycorrhizae, biologists used a fluorescent stain. A blue light was then shone on the stained specimen. When seen through a microscope, the mycorrhizal fungi showed up in fluorescent colours.



Life in the Extreme

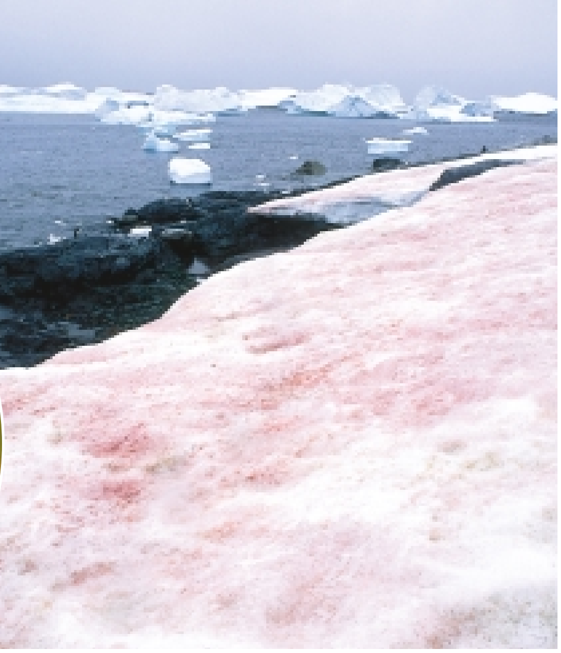
Would you expect to find life at 110 °C? In a salt lake? In the desert sand? In fact, there are organisms adapted to living in all of these extreme environments. The Antarctic springtail, for example, is adapted to the extreme cold. This tiny arthropod produces a type of antifreeze in its tissues, which allows it to survive temperatures as low as -35 °C. Snow algae, which can be found on snowfields around the globe, have cell membranes that are adapted to cold temperatures. Being photosynthetic, the snow algae make their food using the energy of sunlight. However, high in the mountains, sunlight can be very intense. Some snow algae produce reddish pigments that protect against the Sun's damaging rays.

Many organisms have adaptations that defy our current understanding of life. Scientists who are curious about the possibility of life on other, less hospitable planets hope to learn from these strange, earthly species.

DidYouKnow?

Specialized bacteria called archaebacteria make their home in the boiling waters of geysers in Yellowstone National Park, in the United States. The study of heat-loving bacteria led to the discovery of an important heat-stable product used in scientific research.

Figure 1.18 Have you ever seen pink snow? Snow alga is a red alga that is well adapted to living in cold climates. It can be found living on the surfaces of snowfields and glaciers.



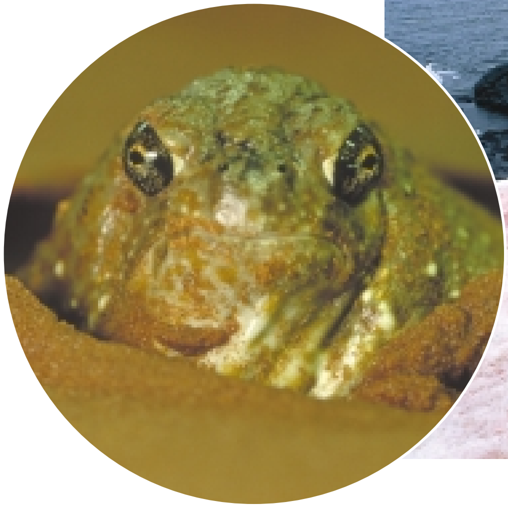


Figure 1.19 The desert spadefoot frog has its niche in the harsh conditions of the Australian desert. This frog can remain inactive for years while buried in the desert sand awaiting rain.

Across Canada

Lemmings do not intentionally jump off cliffs to drown in the sea, as some people may think. Mass movements of these near-sighted little rodents may result in their accidental drowning, however. University of British Columbia ecologist Dr. Deborah Wilson went to Nunavut in Canada's Far North to study lemmings. As part of her study, she looked at their population peaks and crashes, which have led to the cliff-jumping myth.

"Lemming numbers fluctuate quite regularly," Deborah explains, "with peaks in the population every three years. We place small radio transmitters on individual lemmings and follow their movements. This helps us learn whether they become food for predators or whether some other factor is responsible for the steep declines in numbers. Predators (such as arctic foxes and ermine) are responsible for most lemming deaths, but that's not the whole story. Lemmings reproduce at a lower rate when they are very abundant. Whether their lower reproduction is a response to the population density or to a shortage of food or space to live in is not known."

One great thing about working in the North, Deborah reports, "was getting to know the Inuit who lived near our remote field station. Some helped with our field study, and we were able to learn about their culture and the difficulties they face living in an arctic environment."

Deborah started her working life as a computer programmer, but later realized that she would rather be an ecologist. This meant more years of study, but it was worthwhile. "Keep striving to do what you love," she advises students. "It took me a long time to be able to work in the field of ecology, where my real interest lies. It is much less lucrative than working in business, but that doesn't matter to me at all."

TOPIC 2 Review

1. What two things make up an organism's niche?
2. (a) Both red squirrels and grey squirrels live in Alberta, although the grey squirrel was introduced from eastern Canada. Both feed on seeds, nuts, flowers, fruit, insects, and birds' eggs. Do these squirrels have to compete for resources? What are some ways they could avoid competing for resources?

   (b) Would you classify red squirrels and grey squirrels as specialists or generalists? Explain.
3. Describe two examples of symbiotic relationships found in nature. In each example, how do the adaptations of one organism depend on the other's?

Off the Wall

No one knows for sure how they got there, but the bright green parrots of New York City aren't leaving anytime soon. Flocks of the birds make New York their home, where they build nests on high-voltage power poles. The parrots are also called feral parakeets because they are probably descended from pet birds that escaped. It is hard to say if these parrots are generalists or just very lucky specialists!

Wrap-up TOPICS 1-2

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

variation
biological diversity
species
speciation
structural adaptation
behavioural adaptation
diversity index
environment
competition
broad niche
generalist
specialist
narrow niche
specialization
symbiotic association

Reviewing Key Terms

1. In your notebook, match the description in column A with the correct term in column B.

A	B
• a struggle for resources between organisms of the same or different species	• diversity index (1)
• a species with a very narrow niche	• generalists (2)
• the word that describes both the role and the habitat of an organism	• behavioural adaptations (1)
• the many differences between individuals of the same or different species	• competition (2)
• a mathematical expression of the different kinds of organisms in an area	• symbiotic (2)
• a direct or close association between two different species	• variation (1)
• the habits of a species that have been developed over time	• niche (2)
• populations of these organisms tend to be high, although there is not usually very much diversity in the kinds of these organisms	• specialist (2)

Understanding Key Concepts

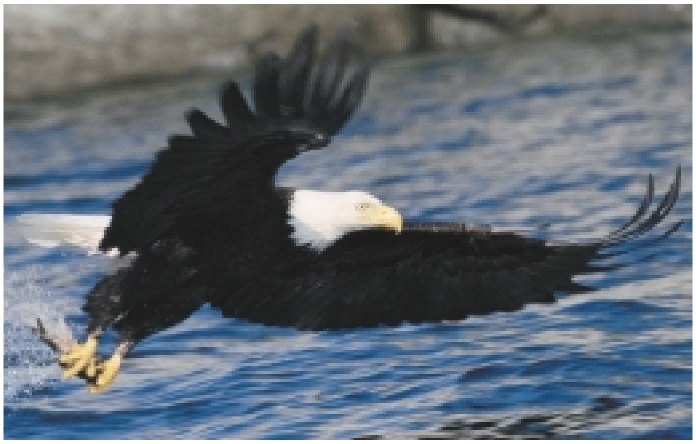
2. Examine the photograph of the eagle. What structural and behavioural adaptations does it have that enable it to obtain food?

3. How could you go about measuring the biological diversity in a tropical area? What would you expect to find? (1) What has happened over time to produce this level of diversity? (2)

4. What are the advantages of a broad niche? When can these advantages turn out to be disadvantages for different species? (2)

5. Define the term "species" using your own words. Are all organisms that look alike the same species? Are all organisms that look different from separate species? Explain your answer. (1)

6. If an area of tropical rainforest were cleared to make room for a farm, how might the local wildlife be affected? Would the consequences be worse for specialists or generalists? Explain. (2)



TOPIC 3 Passing It On

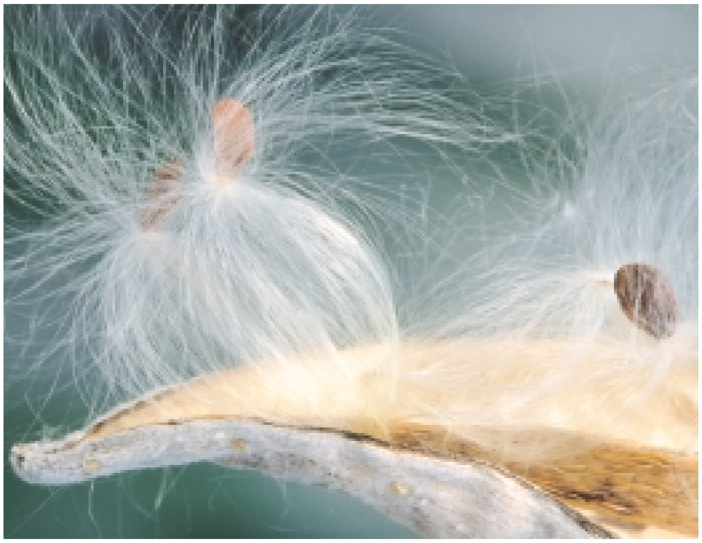


Figure 1.20 This plant reproduces sexually and produces wind-borne seeds.

Everywhere you look there are examples of organisms that look more or less like their parents. How are these characteristics passed on from generation to generation? You have already learned that the characteristics of organisms vary greatly within a species. How does reproduction allow for variation?

Not only do the physical traits of organisms vary, but the ways in which organisms reproduce show variation as well. The plant shown in Figure 1.20 reproduces sexually (see page 32) and uses the wind to disperse its seeds. When a seed germinates the new plant will have characteristics of both its parents. Whether you examine reproduction in bacteria, maple trees, or elephants, you will notice characteristics that are passed on from parent to offspring. These traits are said to be inherited or **heritable**. Such traits are passed on in the genetic material, a subject you will learn more about in Topic 5. Living organisms display a wide variety of methods or **reproductive strategies** for passing on their genetic information to their offspring.

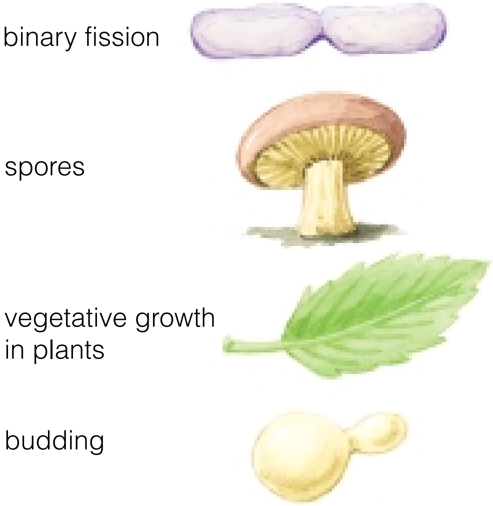


Figure 1.21 Here are some of the diverse forms of asexual reproduction we will look at in this Topic.

Asexual Reproduction

Reproductive strategies may be classified into two major types: asexual and sexual. **Asexual reproduction** occurs when only one parent supplies the information to the offspring. The genetic material of the offspring, and thus their inherited characteristics, are identical to those of the parent. This type of reproduction is common among bacteria and fungi. One advantage of asexual reproduction is that there is no need for an organism to find a mate. Also, reproduction can occur quite rapidly. As long as the environment does not change much, offspring produced by asexual reproduction will be able to survive and reproduce as their parents did.

Pause& Reflect

Organisms pass on their traits in various ways. How would the use of wind-borne seeds increase variation in the plant species shown in Figure 1.20? Record your thoughts on this question in your Science Log as you read through Topic 3.

Binary Fission

Many one-celled organisms such as the amoeba reproduce asexually using a form of cell division called **binary fission**. The cell first duplicates its contents, including its nucleus and other organelles. After the amoeba divides, each new cell has a copy of the genetic material, as well as half of the cytoplasm. As a result, the offspring are identical.

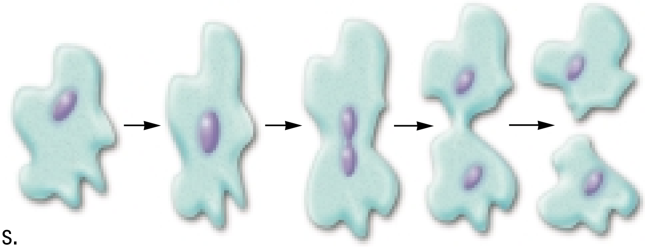


Figure 1.22 Binary fission in an amoeba results in two "daughter" cells.

Asexual Spores

Some fungi, such as mushrooms, can reproduce asexually by forming single-celled, reproductive structures called **spores**. When asexual spores are formed, only one parent organism supplies the genetic material. Many spores are produced to ensure that at least some of them survive. Some fungi and algae, such as the green algae *Chlamydomonas* and *Ulva*, produce **zoospores**, which move using tail-like flagella. Interestingly, fungi can also reproduce sexually — a process we will look at in more detail shortly.

Figure 1.23 The Earth star fungus releases millions of tiny spores.

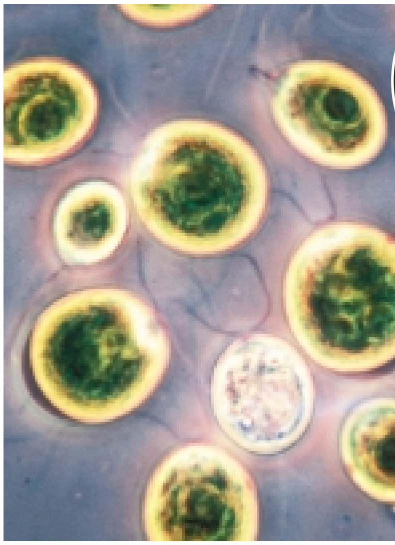


Figure 1.24 *Chlamydomonas* is a unicellular green alga (magnification: 500x). It can reproduce asexually by forming zoospores. Why do you think zoospores have flagella?

Pause& Reflect

Why are relatively few mushrooms seen growing in our yards when the number of spores produced is so high? Write a possible reason in your Science Log.

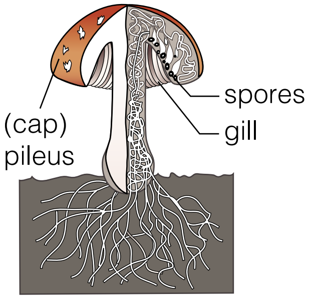
STRETCH Your Mind

Suppose you get on a bus to go to school. At 8:20 A.M., you yawn and a single *Streptococcus* bacterium drifts into your open mouth and settles in your throat. Under ideal conditions, a single bacterium can reproduce by binary fission in 20 min. So, by the time the bus drops you off at school at 8:40 A.M., there are two bacteria in your throat. When your homeroom period starts at 9:00 A.M., there are four.

1. Assume that the bacteria continue to reproduce asexually every 20 min and your body does not fight them off. How many bacteria will be in your throat by: (a) lunchtime (12:00 noon); (b) by the time you get the bus in the afternoon (3:20 P.M.); (c) suppertime (6:00 P.M.); (d) bedtime (10:00 P.M.)?
2. Make a graph showing the growth of the *Streptococcus* population in your throat over the 14 h period. You may create your graph using a computer.
3. Do you think bacteria can keep multiplying in this way indefinitely? Explain.
4. At what time do you think your throat may feel sore? How many bacteria will be present in your throat?

Math CONNECT

How many microscopic spores do you think might be produced by one mushroom? In one species, each of the gills underneath the cap of a single mushroom produces about 13 550 spores on one side of one gill. Keep in mind that each cap of this species of mushroom has about 150 gills. Calculate the approximate number of spores produced by the cap of one mushroom. (Hint: Remember that each gill has two sides.)



Pause& Reflect

Research the African violet and make a sketch in your Science Log of a technique that could be used to grow several African violets asexually from a leaf.

Word CONNECT

Look up the origin of the word "clone." Write a science fiction story that features a clone!

Asexual Reproduction in Plants

You may remember that asexual, or vegetative, reproduction in plants can occur without the formation of special cells such as spores. Unlike many animals, plants continue to grow throughout their lives. The growing tips of roots and stems contain areas of rapidly reproducing cells called **meristem**. At a certain point in the plant's growth, meristematic cells specialize into the cells that make up the roots, stems, and leaves of the plant. If any of these structures are later damaged, the meristem function is activated. Meristematic cells are then able to make repairs to damaged roots, leaves, or the stem of the plant. Asexual reproduction can occur in plants by activating the meristematic cells in different plant structures.

You can make use of the meristem function by taking a cutting and planting it. Cuttings from a parent stem may be used to produce new plants that are **clones** (exact copies) of the parents.

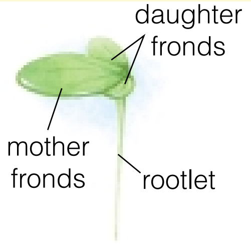
Find Out ACTIVITY

Asexual Reproduction in Duckweed

Duckweed is a very small aquatic plant with leaf-like structures called fronds. Duckweed reproduces asexually by producing two or three daughter fronds from each parent plant. As the daughter fronds grow larger, they break away from the parent frond. Under suitable conditions, a new plant with a genetic program identical to that of the parent may form within 24 h.

Materials

two small jars or culture dishes
100 mL distilled water
100 mL Knop's solution
8 duckweed plants
wax pencil



Procedure

Performing and Recording

1. Examine a duckweed plant. Identify the fronds, rootlet, and daughter fronds. Sketch the duckweed in your notebook.
2. Label two jars or culture dishes: A. Knop's solution and B. distilled water. Place 50 mL of the appropriate solution into each container.
3. Place four duckweed plants into each container and place them in a well-lit area. Wash your hands when you are finished.
4. Over the next two weeks, count and record the number of separate plants in each container. Construct a table to show your results.
5. At the end of two weeks, construct a line graph showing the number of plants that were growing each day. Use two separate lines to compare the numbers of plants growing in the two solutions.

What Did You Find Out?

Analyzing and Interpreting

1. Describe the difference between the parent and offspring plants.
2. How do you think the genetic material in the offspring compares with that of the parent?
3. What was the purpose of setting up one container with distilled water?
4. Which container showed the greatest number of new plants? Why? What does Knop's solution contain?
5. Why do you think that the other dish displayed relatively less growth?

Skill FOCUS

For tips on drawing graphs, turn to Skill Focus 10.

DECISION-MAKING

INVESTIGATION 1-D

SKILLCHECK

Initiating and Planning

✹ Performing and Recording

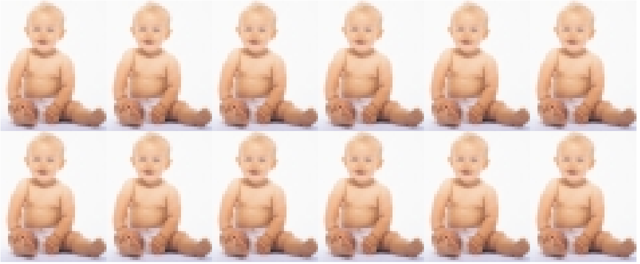
✹ Analyzing and Interpreting

Communication and Teamwork

The Cloning Controversy

Think About It

You may have heard of Dolly the sheep. Dolly is a clone, an identical copy of another sheep. She is the first artificially cloned mammal. Cloning has many applications in the fields of agriculture, medicine, and forestry. However, the possibility of human cloning has attracted the most attention.



Could cloning be used to produce armies of super-soldiers or to make copies of great scientists or professional athletes? Will parents in the future be able to choose children from a catalogue? Laws are being put in place in Canada and other countries that will restrict the cloning of human beings.

Bioethics is the study of moral issues in the fields of medical treatment and research. Although there are many ways of analyzing bioethical issues, there are certain steps that are common to all discussions. In this investigation, you will consider the bioethics of cloning human beings. What are the advantages and disadvantages of human cloning? Should there be any controls on the experimentation? Might there be health risks for human clones that scientists are not aware of? Who should be allowed to perform human cloning and under what conditions?

How Can Science Help?

Scientists must first understand cell structures and processes in order to identify ways to clone organisms. To test their hypotheses about cloning, they must conduct many investigations. They must then make long-term observations of cloned mammals in order to monitor their health and check that their development is normal. This is important in order to know whether or not human cloning would be safe.

Procedure

1. State what is involved in the cloning issue. This may be in the form of a question or a statement describing the dilemma, but it should summarize the issue briefly and clearly.
2. Gather information on cloning from newspapers, magazines, Internet sites, or television or radio broadcasts. How will you collect and record this information?
3. Present possible alternatives. Consider alternatives such as permitting the cloning of some species but not humans.
4. Identify different perspectives on the issue. Who would want to speak on this issue? Think of as many people or groups as possible.
5. Identify potential benefits and concerns for each alternative. Which alternative is likely to be most acceptable by the community?

Analyze

1. Choose one of the following ways to analyze this bioethical issue.

- Write out your analysis of the issue in the form of a magazine or journal article.
- Create a poem, play, or story that presents your analysis of the issue.
- Make a poster that shows your position on the issue and your reasoning.

Skill FOCUS

For tips on societal decision making, turn to Skill Focus 8.

Off the Wall

The Mexican whiptail lizard reproduces asexually. The females lay eggs, which develop into baby whiptails. The strange thing about these lizards is that the eggs are never fertilized by male whiptails. In other words, the offspring have only one parent! These offspring end up with the same genetic information as the mother lizard.

Budding

Some animals, such as sea sponges and hydra, reproduce asexually by **budding**. A cell, usually near the base of one of these organisms, produces a new group of cells called a bud. When the bud has completely developed, it detaches itself and becomes independent. Yeast cells also reproduce by budding. The bud, which contains its own nucleus, eventually becomes a single, indepedent cell.

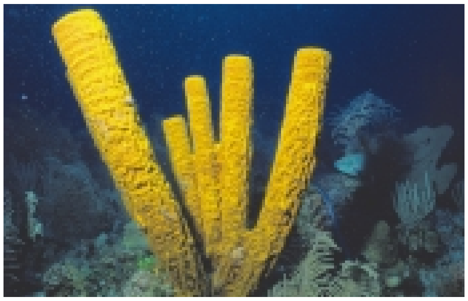


Figure 1.25 Sponge buds may remain attached to the parent, which results in a colony. What advantage does the bud have by being attached to its parent?

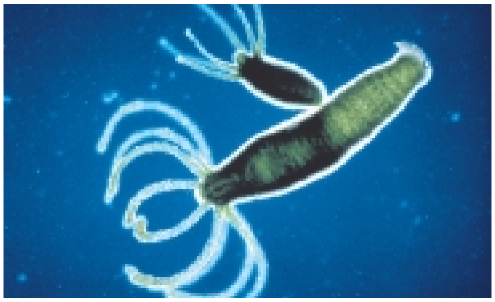
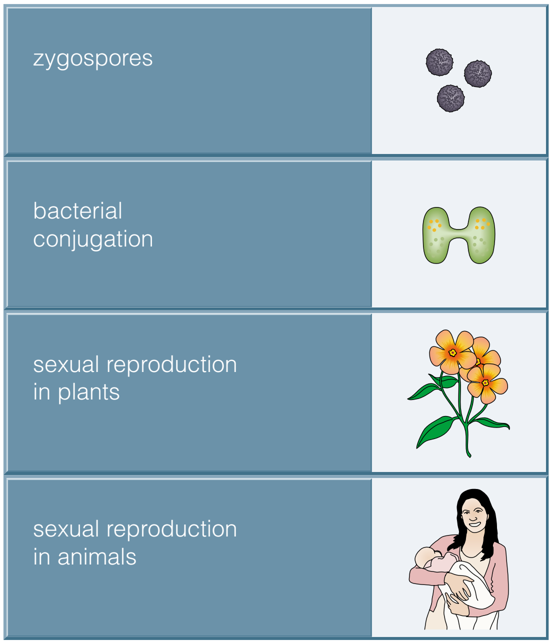


Figure 1.26 Hydras are very small organisms that live in water. Based on what you have learned about budding, describe what is happening in this picture.

Sexual Reproduction

In general, **sexual reproduction** occurs when two parents supply genetic material to the offspring. Since both parents supply the genetic material, the offspring will not be exactly like either one. Instead, the offspring will display a combination of characteristics from both parents. While new combinations of characteristics occur in organisms that reproduce sexually, new combinations do not occur with asexual reproduction. Can you think of some reasons why involving two parents in reproduction might be a useful adaptation?

Figure 1.27 Different organisms use various forms of sexual reproduction. In fact, many organisms are capable of both sexual and asexual reproduction! Some of the forms of sexual reproduction we will examine are shown here.



The Best of Both Worlds

Many organisms are capable of both asexual and sexual reproduction. As you learned earlier, in order to reproduce asexually, some moulds, such as *Rhizopus*, produce spores. Spores may be black, blue, yellow, red, or some other characteristic colour. *Rhizopus* can also reproduce sexually by forming **zygospores**. As shown on page 31, unlike asexual spores, zygospores contain genetic material from two different sources.

Did You Know?

When each sporangium, or spore case, splits open, it releases spores that float about on air currents. Airborne spores have been found in the atmosphere at altitudes of more than 160 km.

INQUIRY

INVESTIGATION 1-E

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Making a Mould

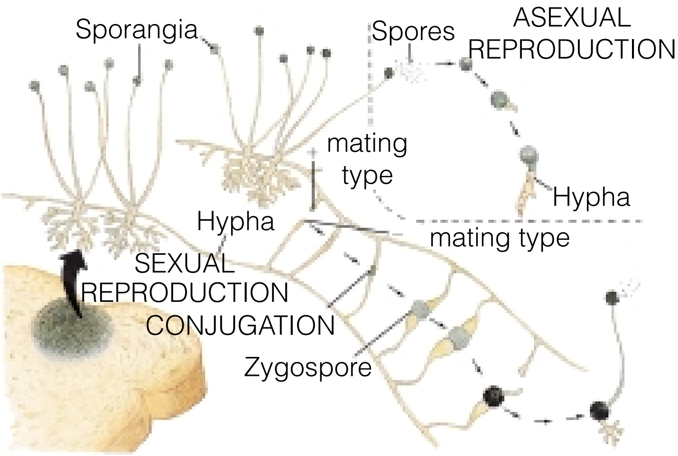
You know that mould will grow on bread, but does any kind of bread provide the right food source? Is there a difference between homemade bread and store-bought bread? What other conditions must be present for bread mould to grow?

Question

Are certain conditions required for the growth of bread mould?

Hypothesis

With your group, agree on a hypothesis about why bread becomes mouldy in certain situations.



Long strands of cells called hyphae grow out of the *Rhizopus* spores. Where the tips of two hyphae touch, a zygospore, which contains genetic material from both hyphae, is formed.

Safety Precaution

- Mould is a biological hazard.
- Never inhale mould spores.
- Wash your hands after removing your gloves.

Apparatus

culture dishes
microscope or dissecting scope
camera (optional)
tweezers

Materials

disposable gloves
different types of bread
sealing tape
water
blank paper
pencils

Procedure

① With your group, **design** a procedure that will allow you to test your hypothesis. Based on your hypothesis, **predict** what you expect to **observe**.

② In your design proposal be sure to include your hypothesis, prediction, the materials you will need, how you will **record** your observations, and the steps you will follow to conduct your research. You should include the use of a low-magnification microscope or dissection scope to examine the bread for results. Be sure to include steps for proper disposal of materials at the end of the experiment.

③ When you have received approval from your teacher, conduct your experiment.

④ Wash your hands after this investigation.

Analyze

1. Describe your results. Use charts, diagrams, or photographs. Write brief descriptions to accompany your illustrations.

Conclude and Apply

2. Did your results support your hypothesis? Why or why not? Did other groups get similar results using their procedures?

3. How well does mould grow in different situations? Under what conditions did you observe the most mould growth?

Extend Your Skills

4. With your group, design an experiment to answer additional questions you have about the growth of mould.

Skill FOCUS

For tips on designing your own experiment, turn to Skill Focus 6.

Bacterial Conjugation

Bacteria are able to transfer genetic material directly from one cell to another in a process called **bacterial conjugation**. As with conjugation in fungi, bacterial conjugation is a primitive form of sexual reproduction since two parent cells are involved. The benefit is that new combinations of inherited characteristics may be produced as a result.

It is interesting to note that bacterial conjugation results in genetic recombination but not reproduction, because there is no increase in the number of cells. Following conjugation, new cells will be produced by binary fission. At this time, the newly recombined genetic material (and characteristics) is passed on to the new cells.

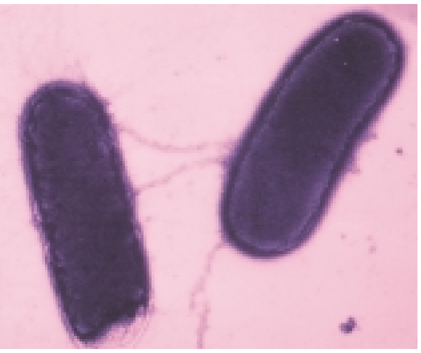


Figure 1.28 In bacterial conjugation a connection forms between two cells. The one-way transfer of genetic material from one cell to another can then occur.

Sexual Reproduction in Plants

Plants have developed diverse adaptations and structures for reproduction. Ferns and mosses reproduce by forming spores. Angiosperms and gymnosperms reproduce sexually by forming seeds. As you may recall from your earlier work, angiosperms are flowering plants. Over half of all known plant species are angiosperms. Some have large and showy flowers like dahlias, chrysanthemums, or dandelions. Others, such as the flowers of grasses, are hard to see. Why do you think there are so many different kinds of flowers?

You may remember that gymnosperms do not produce flowers. Instead, they produce seeds inside of cones, which is why the largest group are called conifers. You are probably familiar with conifers such as spruce, fir, and pine.

Figure 1.29 Some angiosperms, such as these sunflowers, have large blossoms.

Did You Know?

Some harmful bacteria are able to resist medicines such as antibiotics. Antibiotic resistance is a heritable trait. One bacterial cell can quickly pass this trait on to another through conjugation. As a result, the spread of antibiotic resistance in bacteria is very hard to control.

Pause & Reflect

There are about 35 000 species of spore-bearing plants, 700 species of gymnosperms, and 200 000 species of angiosperms living on Earth today. Why do you think angiosperms are so successful? Record your thoughts on this question in your Science Log as you read through the rest of Topic 3.

Did You Know?

Like angiosperms such as maples, ginkgo trees shed their distinctively shaped leaves in autumn. However, ginkgoes are actually gymnosperms, and the last of an ancient group whose other members are now extinct.

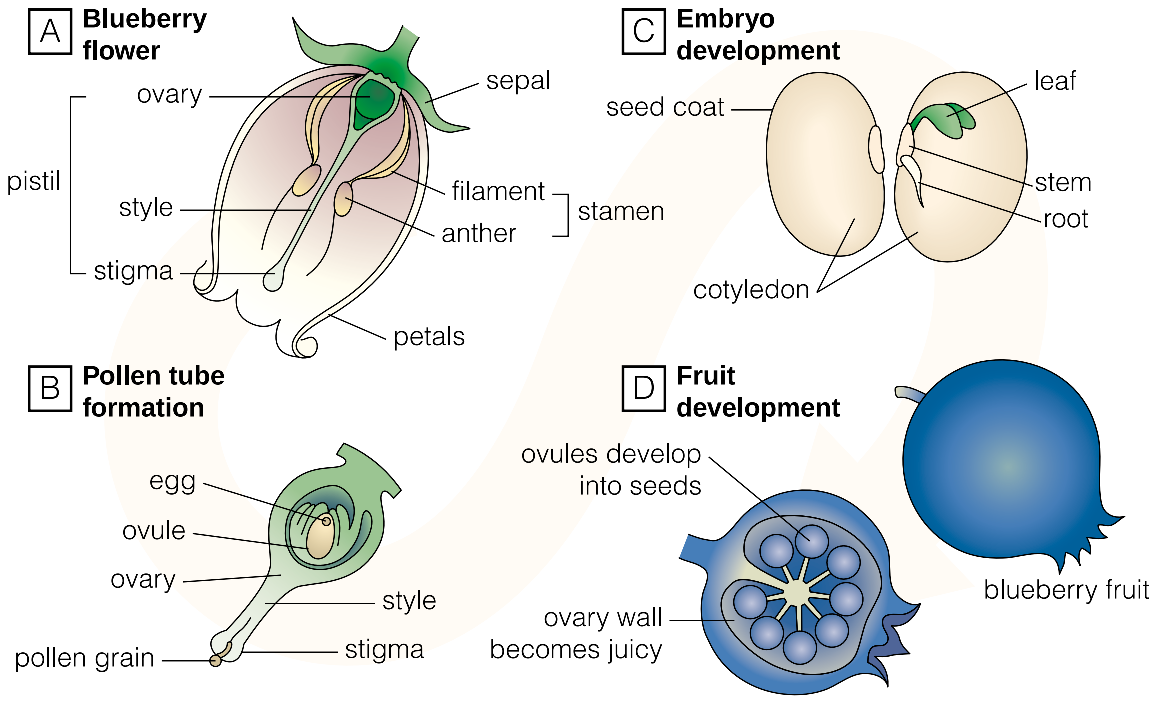


Figure 1.30 **A** The stigma, style, and ovary make up the pistil, the female part of the flower. The anthers, which are supported by the filaments, produce and store pollen grains containing sperm nuclei. Each stamen is composed of an anther and a filament. **B** When a pollen grain lands on the stigma, a pollen tube is formed. A sperm nucleus then travels down the tube to fertilize one egg. **C** Prior to fertilization, other cells in the ovule have been developing into a cotyledon, a structure that nourishes the embryo. Blueberry plants are dicotyledons, which means two cotyledons surround the embryo in each seed. **D** In angiosperms, a fruit, such as a pod, nut, or the fleshy fruit of a berry, surrounds the developing seeds. The fruit usually develops from the wall of the ovary.

In sexual reproduction in plants and animals, fertilization occurs when an egg and sperm cell, the female and male gametes, join to form a new cell. The first cell of the growing organism, which contains genetic information from both parents, is called a **zygote**.

You may recall that flowers are the reproductive organs of angiosperms. The female reproductive organ is called the **pistil** and the male reproductive organ is the **stamen**. Figure 1.30 shows the egg contained in the **ovule** at the base of the pistil. Pollen grains, each of which contains a sperm nucleus, are produced on the plant's stamens. Try to locate some of these reproductive structures on a real flower.

Pollination occurs after pollen reaches the pistil of a flower. As you can see in Figure 1.30, the pollen grain grows an extension called a **pollen tube**. The pollen tube grows into the pistil until it reaches the ovule. Once the pollen tube has reached the ovule, the sperm nucleus travels down the tube to fertilize the egg. The zygote then undergoes many cell divisions to form a multicellular **embryo** containing a miniature leaf, root, and stem. The embryo is supplied with food by one or two **cotyledons**, and together these structures make up the developing seed. When growing conditions are good in terms of warmth, moisture, and oxygen in the soil, the seed will germinate.

Pause& Reflect

In **self-pollination**, both sperm and egg cells come from the same plant. However, wind, water, insects, birds, and other animals often carry pollen over from one plant to another. In this case, **cross-pollination** occurs. In cross-pollination, gametes from two different parent plants are involved. Gardeners who grow orchids and other expensive show-flowers, often keep the flowers in enclosed greenhouses. Why? Why do you think cross-pollination would be a useful adaptation for plants in the wild? Why would self-pollination be an advantage in some cases? In your Science Log, list the advantages of cross-pollination and self-pollination.

Pause& Reflect

The Western wood lily grows wild in Alberta and Saskatchewan. Unfortunately, over-picking has made the flower rare in some areas. Picking the flowers damages the leaves that nourish the bulb. What advantage does the Western wood lily have by being able to reproduce asexually from bulbs? Does reproduction from bulbs add to variation in this species? How is variation increased in this wild flower? Write you answers in your Science Log.

Plants Reproduce Sexually and Asexually

Many plants have adaptations for both sexual and asexual reproduction. As you have seen, some plants reproduce asexually from meristem cells. For instance, the bulbs of some flowers are really modified leaves that store food for the plant. A new plant may emerge when the bulb is planted in the soil. Why do you think angiosperms, which can reproduce sexually, have adaptations for reproducing asexually?

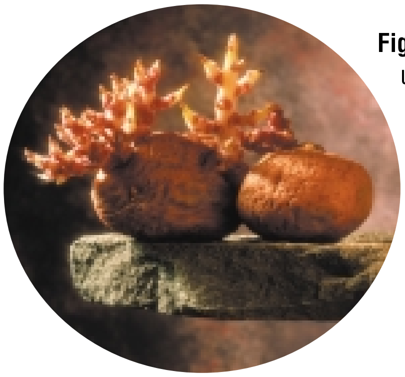


Figure 1.31A The potatoes we eat are actually part of an underground stem called a tuber. The eyes of the new potato are the buds of a new plant. These plants reproduce asexually by growing new shoots from underground stems.

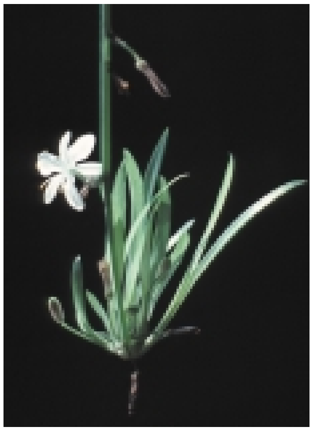


Figure 1.31B The spider plant reproduces asexually from special stems, called runners, shown here hanging from the main plant. Strawberries reproduce by forming runners that lie on the ground. Lilacs spread by producing suckers, which are outgrowths of the root or the lower part of the stem.

Pause& Reflect

At one time, large spore-bearing plants were the most numerous of all plant species. In your Science Log, write a hypothesis to suggest the type of climate Earth must have had to support such populations of spore-bearing plants. Infer how climate change can affect plant survival. Hint: mosses and ferns require moisture to complete the sexual stage of reproduction.

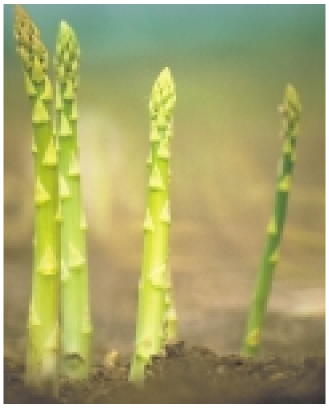


Figure 1.31C Asparagus is a flowering plant and part of the lily family. Asparagus plants die back to the ground in the winter. In the spring, new plants regrow from their roots. Since it is very easy to grow plants such as asparagus from the roots, growers may sell only the roots instead of the whole plant. Can you think of some advantages and disadvantages of developing and selling plants this way?

Figure 1.31D The life cycle of mosses is referred to as the alternation of generations. This is because during one part of the cycle, asexual spores are produced; in a later part of the cycle, egg and sperm cells are produced. The spores, which are produced in large numbers, are able to withstand unfavourable temperatures and dry conditions. They are also very light and can be carried great distances to locations with better growing conditions. On damp ground, a spore can develop into new moss. Sperm cells produced by the moss then swim to egg cells to complete the sexual stage of the life cycle.

Sexual Reproduction in Animals

Animals have many different reproductive strategies. In all cases for sexual reproduction to be successful in animals (or plants), certain requirements must be met. Both male and female gametes must arrive in the same place at the same time for fertilization to occur. The zygote requires specific conditions in order to develop. It needs enough nutrients and moisture, and in some cases, warmth and protection.

Gametes are delicate and dry out quickly. Their life spans are short, so the release of eggs and sperm must be carefully timed. A liquid environment is important because it prevents drying and gives the sperm a fluid to swim through to reach the egg. In animals such as sponges, most worms, and many fish and amphibians, fertilization occurs outside the female. However, in insects, reptiles, birds, mammals, and some fish and amphibians, fertilization occurs within the body of the female. Why might internal fertilization be a useful adaptation for life on land?

STRETCH Your Mind

While mating, a female frog may try to dislodge the male who embraces her. Only males that can remain attached long enough will fertilize the eggs. How might this behaviour affect the characteristics of the offspring?

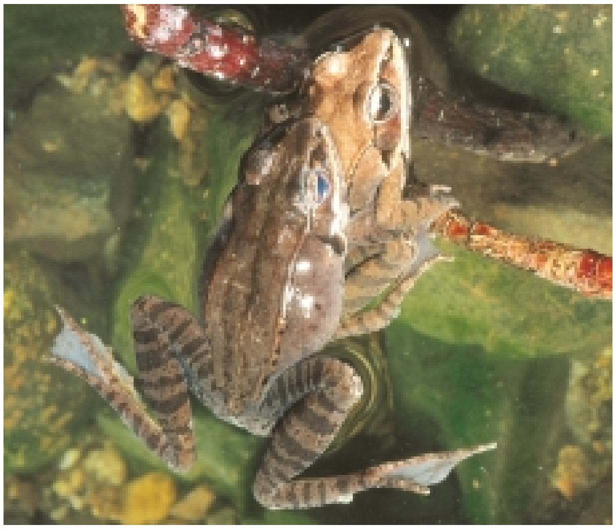


Figure 1.32 When frogs mate, the male and female release gametes into the water at the same time. With external fertilization, the risk to the sperm is extreme. Water must be present in order to keep the eggs and sperm alive. Fish or other animals may eat the gametes or water currents may sweep the sperm and eggs away from each other. Extreme temperatures, pollutants, or lack of oxygen may destroy the gametes. Since the majority of gametes are wasted, large numbers must be produced so that at least some will survive. Those that do may form zygotes, which will develop in the water.

Mammals carry out internal fertilization, which is one of the reasons for their high rate of successful fertilizations, or reproductive success. With internal fertilization, egg cells are protected inside the body of the female parent where conditions are warm and moist. Sperm deposited by the male in the female's body moves almost directly toward the egg, so risks to the survival of the gametes are greatly reduced.

If a mature egg cell is present, fertilization may occur. As with flowering plants, the egg and sperm join to form a zygote. In the early stages of development, after the zygote grows and divides many times, it is called an embryo. In most mammals the embryo develops close to or within the female's body.

Off the Wall

When sponges reproduce sexually, they use internal fertilization. Because sponges cannot travel for mating, sperm must be released externally into the water. Once the sperm find their way to another sponge, they are captured by special cells, taken into the sponge's body, and transferred to the eggs internally.

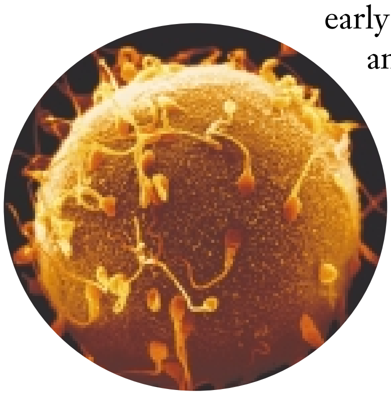


Figure 1.33 Internal fertilization removes the dangers of harsh climates and possible predators. The moist environment also helps the flagellated sperm to swim to the location of the egg within the female reproductive tract. As shown here, many sperm will reach the egg. However, only one sperm will fertilize the egg to form the zygote.

DidYouKnow?

The duck-billed platypus and the echidna are the only mammals that lay eggs. However, like other mammals, the young are fed their mother's milk and protected until they can look after themselves.

Figure 1.34 The female opossum gives birth to offspring that are smaller than a honeybee. To complete their development, they must remain in the mother's pouch for another three months.

Figure 1.35 The reproductive cycle of mammals and birds requires a great deal of one or both parents' energy.

Off the Wall

Many gastropods such as snails and slugs are hermaphrodites: each individual has both male and female reproductive organs. This is called simultaneous hermaphroditism. Others, however, are sequential hermaphrodites. They are male when younger and female when older and large enough to produce and carry eggs.

Pause& Reflect

There is great diversity in the strategies different organisms use to reproduce. Do you think that reproductive success contributes to variation within a species? How is biological diversity related to reproductive success? Answer these questions in your Science Log.

TOPIC 3 Review

1. Explain the difference between budding and binary fission.
2. **Apply** Name one type of organism that reproduces both sexually and asexually. Explain how this can occur.
3. In what way is conjugation a primitive form of sexual reproduction?
4. Describe the exact location of the egg cell and sperm nucleus of a flowering plant.
6. **Thinking Critically** Salmon lay eggs, while whales give birth to live young. Which animal do you think probably produces more young at one time: the salmon or the whale? Explain your choice.
5. **Thinking Critically** Fireweed flowers are shaped so that they cannot pollinate themselves. Near the end of the growing season, however, a change occurs in any flower that has not been pollinated. The stamens curve around so that the anthers touch the stigma within the same flower.
   - (a) Explain the reproductive advantage of preventing self-pollination in fireweed.
   - (b) Explain the reproductive advantage of permitting self-pollination in fireweed.

TOPIC 4 Wearing Your Genes

Why do some people have blue eyes while others have brown eyes? What makes some people redheads and others brunettes? Are some people born great musicians, or do their talents simply develop with practice? We know that certain characteristics are passed on from one generation to another, but sometimes strange things seem to happen. You may know someone who is the "jock" of her family, while her brother can't throw a ball straight no matter how hard he tries. For thousands of years, people have tried to explain how parents' traits are passed on to their children. Why are some characteristics passed on and others are not? Does one parent have more influence than the other? Why are some traits more common than others? Are all characteristics passed on in the same way?

The passing on of traits from parents to their offspring is called heredity. The branch of science that deals with the study of heredity is called **genetics**.

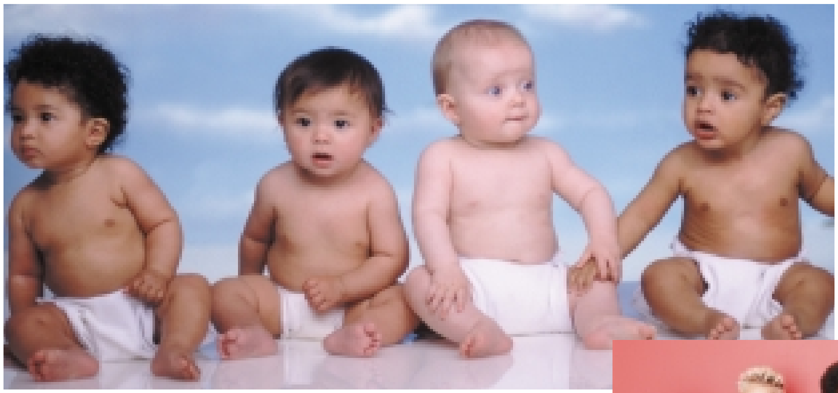


Figure 1.36 There is a wide range of human skin colours.

Two Kinds of Inherited Variation

At the beginning of this unit you looked at variation within the students in your class in terms of characteristics like height and hand span. These are examples of **continuous variation**. Many human characteristics such as skin colour, height, and hair colour show this form of inheritance. There is a range of possibilities for each of these traits, like percentages given on a report card.

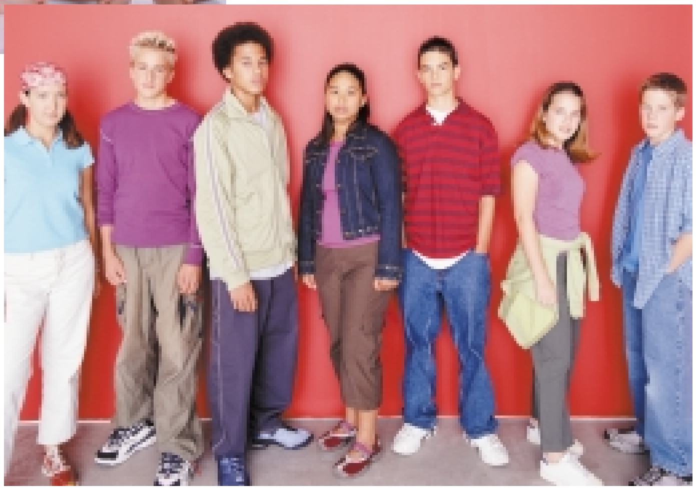


Figure 1.37 We may think of people as tall or short, but people can fall anywhere between these two extremes.

Did You Know?

How many people do you know who are left-handed? Do you think being left-handed is an inherited trait? Actually, no one knows for sure — not even scientists!

Other characteristics are examples of **discrete variation**. These characteristics have a limited number of possibilities. For example, the ability to curl your tongue is genetic. There are only two possibilities: you can do it or you cannot. The ABO blood group is another example of a discrete genetic characteristic. In this case there are four possibilities: blood group A, B, AB, or O. Sex (male or female) is another example of discrete variation. Discrete variation is like a report card that uses letter grades such as A, B, C, D, or F. Our knowledge of genetics is focussed on "discrete" characteristics because they are easier to understand and test.

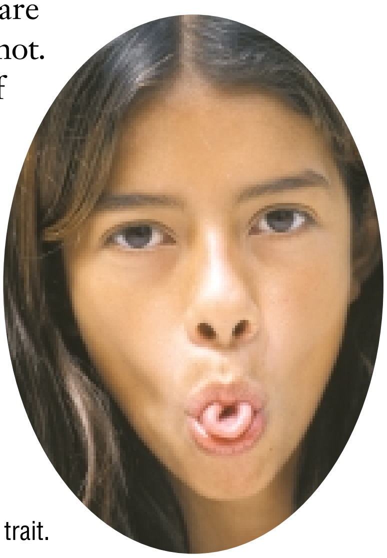


Figure 1.38 Tongue rolling is a genetic trait.

Find Out ACTIVITY

Observing Human Characteristics

Every person is a collection of characteristics, or traits. Some traits occur in distinct forms. For example, your hairline can be either smooth or pointed. In this activity, you will observe some traits displayed by your fellow students.

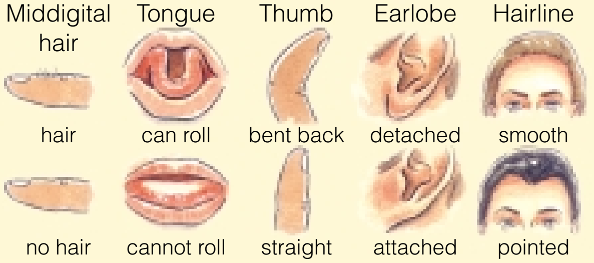
Procedure

Performing and Recording
Communication and Teamwork

1. Study the forms of each trait shown in the illustrations. Copy and complete a table such as the one below, using the total number of students in your class.

Characteristic	Middigital Hair		Tongue		Thumb		Earlobe		Hairline	
Traits	Hair	No Hair	Can Roll	Cannot Roll	Bent Back	Straight	Attached	Detached	Smooth	Pointed
Student 1										

2. In your table, check off which of the two forms of each trait each class member displays. Plot your results on a bar graph.



Skill FOCUS

To review how to prepare a bar graph, turn to Skill Focus 10.

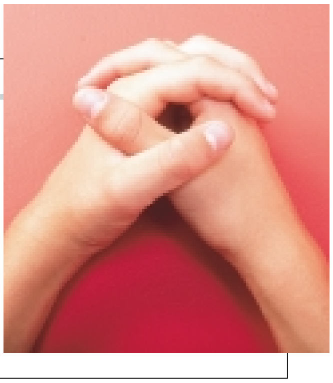
What Did You Find Out?

Analyzing and Interpreting

1. Are some forms of a trait more common than others?
2. What can you conclude about the way traits vary among your class members? Why do you think some students show one form of a trait while others show a different form?
3. Do you think most traits are continuous or discrete?

Pause& Reflect

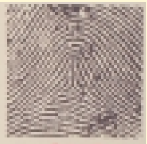
Bring your hands together and interlock your fingers. Which thumb is on top? Try bringing your hands together with the other thumb on top. For most people this is very uncomfortable. Believe it or not, the tendency to bring your hands together in a particular way is a genetic trait. Some people will put the left thumb on top while others will put the right thumb on top. Unlike most genetic traits that we know of, this one is not a structure that is inherited but a behaviour. If this simple behaviour is genetically controlled, what other behavioural traits are also controlled this way?

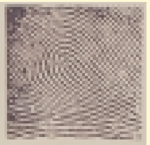


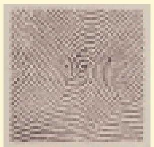
Find Out ACTIVITY

Dermal Ridge Counts

Did you know that fingerprint patterns are inherited? Yours will look something like one of the types shown here. Because fingerprints show continuous variation, your fingerprints may have any number of ridges. A dermal ridge count is simply a count of the ridges in your fingerprints.


Arch


Loop


Whorl

Materials

magnifying glass
inkpad with non-toxic ink
unlined paper
chalk

Procedure

Performing and Recording
Communication and Teamwork

1. Press your fingertips on the inkpad. Then press your fingertips onto the paper without smudging the prints. Press your fingertips onto the paper a second time if you used too much ink for the first set. Wash your hands when you are finished.
2. Use a magnifying glass to study your fingerprints. If possible, count the ridges for every fingerprint. For an arch fingerprint, record the number of ridges as zero. Record your totals in your notebook.
3. Add the numbers for all ten fingerprints. This will be your total dermal ridge count. Record this number on the chalkboard along with the other students' results.
4. Group the data into categories: everyone's total dermal ridge count should fall into one of the groups. Count the number of students in each group. For example, you may note that there are five students with total dermal ridge counts between 140–159, and three students with counts between 160–179. Draw a histogram showing the range of dermal ridge counts in your class.

What Did You Find Out?

Analyzing and Interpreting

1. Which one of the three kinds of fingerprints do you have?
2. What is your dermal ridge count? How does it compare with the counts of other students?
3. Why do you think there are so many different dermal ridge counts? (Hint: Fingerprint patterns are inherited from both parents.)
4. Is there a difference between the total dermal ridge counts of the girls versus the boys in your class? What is the difference between the highest and lowest dermal ridge counts for the boys? The girls?
5. Where in your histogram do most counts fall? How many people have counts at either end of the graph?

Computer CONNECT

Use a spreadsheet application to sort the raw data. Group the data into categories. Then use the spreadsheet to generate a computer graph.

Dominant or Recessive?

Children inherit their genes from both parents. However, children do not always show their parents' traits. During sexual reproduction, traits like tongue rolling are passed from parents to offspring. If one parent gives the characteristic for tongue rolling and the other parent gives the "non-roller" characteristic, the child will be able to roll his or her tongue. Tongue rolling is an example of a **dominant** characteristic. Non-rolling is a recessive characteristic. A dominant characteristic shows up when mixed with a **recessive** characteristic.

Many people connect the frequency of a characteristic with whether it is dominant or recessive. People often assume that if a trait is widespread in a population (has a high frequency), then it must be dominant. However, dominance and frequency are not the same. The frequency of a trait can vary from population to population. In some populations almost everyone has the recessive traits of blue eyes and blond hair. Other populations are made up entirely of people with brown eyes and black hair. Having six fingers is a dominant trait, but it is relatively rare in human populations.

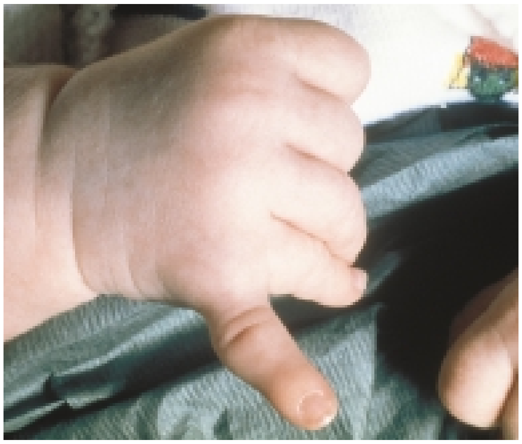


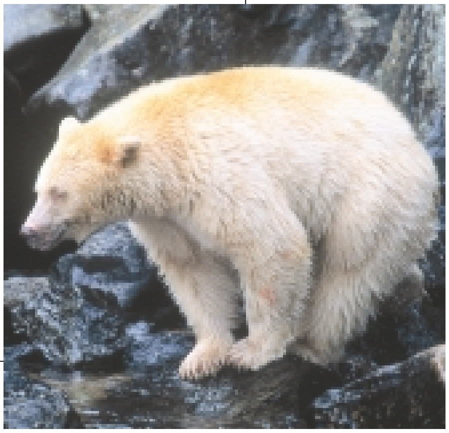
Figure 1.39 Polydactyly (having six fingers) is a dominant trait.

Word CONNECT

Break the word "polydactyly" into two parts. "Poly" means "many" and "dactyl" refers to fingers. Thus, "polydactyly" really means "many fingers." Write down some other words that begin with "poly." Look up more words in the dictionary to add to your list.

Off the Wall

Have you ever heard of a white black bear? People are not the only organisms to show dominant and recessive traits. The Kermode bear of British Columbia is a rare type of black bear (*Ursus americanus*). This bear has white fur, which is a recessive trait.



Pause & Reflect

In general, brown eyes are dominant to blue eyes. However, eyes come in many shades of blue, brown, and even green. The person in this picture has hazel eyes, which are a mixture of green and brown. How can you explain the variety in human eye colour? In your Science Log, make a note of this and other questions that come up as you read through Unit 1.

Math CONNECT

Asparagus has a curious effect on people: after eating asparagus, people excrete bad-smelling compounds in their urine. However, not everyone is able to smell these compounds. Scientists believe that the ability to smell these compounds is a dominant trait. In a study conducted at a university, 18 out of 81 students could smell the bad-smelling compounds in urine. What was the frequency of "smellers" in the university class? What was the frequency of "non-smellers" in the class?

THINK & LINK

INVESTIGATION 1-F

SKILLCHECK
- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Inheritance of Human Characteristics

Think About It

There is no single rule that explains how human characteristics are passed on from parents to their children. Some inherited characteristics seem to be "stronger" or dominant and more likely to show up than others. In this investigation you will look at different traits of one child and his or her parents. Your teacher will supply you with images of the family members.

What to Do

1. Earlier you observed various human traits among students in your class. Choose four human characteristics (or more) and create a chart, such as the one shown here. Intermediate characteristics are ones that are in between the traits of both parents.
2. Compare the characteristics of the child with those of the parents. Record the data on your chart.

Characteristic of child	Same as both parents	Same as one parent	Intermediate characteristic	Different from both parents
dimples				
medium height				
attached earlobes				
pointed hairline				
left thumb on top of clasped fingers				
no middigital hair				
brown hair				

Analyze

1. Which characteristics do you think are discrete and which ones are continuous?
2. Compare your results with other students. Did other students get the same results as you did? Give examples.
3. Did other students get different results from yours? Give examples.
4. What conclusions can you draw from these results?
5. Which of the characteristics that you have studied do you think are dominant and which ones are recessive?
6. **Apply** How could you find out if a characteristic was dominant or recessive?

Nature Versus Nurture

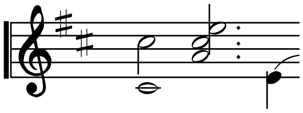
Not all characteristics are inherited. Some characteristics depend entirely on the environment. For example, scars and injuries are not caused by genetics. In addition, clothing, hairstyle, makeup, and even cosmetic surgery can alter a person's characteristics. However, a person's weight is due to a combination of factors such as genetics, diet, and activity level. The interactions between a person's genetics (nature) and the environment (nurture) are complex and not well understood. The balance between the two is continually being debated. Some believe that "all people are created equal." They argue that a person's characteristics are due to his or her opportunities and choices. Others believe that heredity is responsible for all of someone's traits, including a person's likes and dislikes. The debate on the roles of heredity and the environment in determining human characteristics continues today.

Modern science has tried to separate traits that are inherited from those that are influenced by the environment. One way that has been used is to study the similarities and differences between identical twins who have been separated at birth and raised in different environments. Since identical twins have the same genetic information, they share many inherited traits. Some of the results of these studies are highly controversial and hard to explain. In one example, a pair of identical male twins were separated when they were five days old. When they were reunited, many years later, it turned out that they were both volunteer firefighters, had the same type of moustache, and wore the same style of sunglasses. Some people argue that examples such as this show that many complex behaviours are inherited.

We now know the environment and our genetics interact to produce many of our characteristics. At this stage, however, we still have a lot to learn.

DidYouKnow?

Why is it that some people cringe when they hear a wrong note, while others don't even notice? Studies show that identical twins tend to have the same ability to recognize mistakes in tunes. This means that, to some extent, the ability to recognize wrong notes is inherited. Studies also show that musical experience plays a role in this ability.



DidYouKnow?

Body size is not always a matter of genetics. Women who smoke while pregnant tend to have smaller babies than women who do not smoke during pregnancy. Smaller babies may have more health problems.

Changing Our Genetic Information

Our genetic information itself can be changed by factors in the environment and by random errors. These changes to DNA, the genetic material, are called **mutations**. Mutations can cause changes in the structure of organisms, including people. X rays, ultraviolet rays, cosmic rays, and some chemicals are called **mutagens** because they cause mutations. Sometimes mutations have little or no effect on an organism, but often they can disrupt the complex interactions of chemicals and cells that are necessary for life.

In some cases, mutations in individual cells cause cancer. Cancerous cells go through rapid cell divisions and do not develop in the same way that healthy cells develop. The cancerous cells can interfere with nearby cells and prevent the body from performing normally.

If mutations occur in the DNA of reproductive cells (sperm or eggs), the changes may be passed on from parent to child. These changes in the genetic material increase the variation within a species. Usually the mutations result in variations that are unfavourable. Occasionally, however, the new variations are harmless or even beneficial.

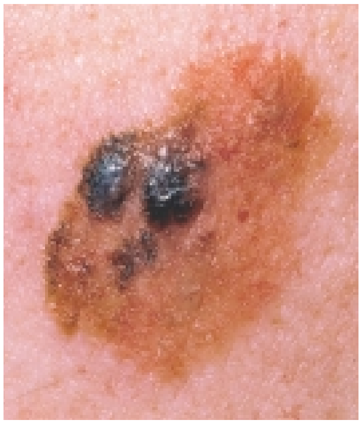


Figure 1.40 The dark spot shown in this photograph is skin cancer. About 20 000 Canadians develop skin cancer every year, and 500 to 600 die from it. Which environmental factor contributes to the development of skin cancer?

Did You Know?

In 1986 a nuclear reactor exploded in Chernobyl, Ukraine. Some of the people exposed to the highest levels of radiation in this disaster were the clean-up crew. Later, some of the clean-up crew had children. It is now known that these children have high rates of mutations in their genetic material. These mutations were inherited from their parents.

Did You Know?

Sickled, or deformed, red blood cells are caused by a mutation. Sickle cells are a recessive trait, and people with this trait are very ill. However, when the sickle-cell trait is mixed with the dominant normal-cell trait, the mutation is beneficial. In this case, people with the mutation are less likely to catch the disease malaria.

Find Out ACTIVITY

Reducing Cancer Risks

Our risk of getting some cancers, such as melanoma, or skin cancer, can be greatly reduced by staying out of the Sun during peak periods of ultraviolet radiation. Making other simple lifestyle choices, such as not smoking, can also greatly reduce our risk of developing lung or throat cancer.

Procedure

- Initiating and Planning
- Analyzing and Interpreting
- Communication and Teamwork

1. In your group, brainstorm a list of questions related to cancer and lifestyle. For example: What chemicals are thought to cause cancer? What are the most common types of cancer in Canada? What are the rates of these cancers in women and men? How do these compare with cancer rates in your community? What lifestyle changes could you make to reduce your risk of getting these cancers?
2. Next, brainstorm a list of possible resources and institutions in your community where you could get information about cancer. Make a list of web sites and collect pamphlets, if they are available.
3. Use your information to design a web site or create a poster by hand or on a computer. Present your findings to the class. You may electronically send your poster to other schools for display.

THINK & LINK

INVESTIGATION 1-G

SKILLCHECK

Initiating and Planning

Performing and Recording

☀ Analyzing and Interpreting

☀ Communication and Teamwork

Causes of Human Variation

Think About It

You have learned that some human characteristics are inherited and others develop as a result of environmental factors. How do genetics and the environment combine to increase human variation?

What to Do

Make a chart listing at least 10 of the human characteristics that have been mentioned in this Topic. Like the sample chart shown on the right, your chart should include columns for Nature (genetics), Nurture (environment), Both, and Unknown. Use the information in this Topic and other sources to decide if the characteristic is controlled by genetics, the environment, by a combination of both, or if this information is not known.

Human Characteristics	Nature	Nurture	Both	Unknown
left handedness				✔
skin colour			✔	

Analyze

1. According to your data, what is the most important factor that determines human characteristics? Explain.

2. Make a bar graph to illustrate your data.

Conclude and Apply

1. Do you think all types of human characteristics are represented on your chart? Explain.

2. Why are some characteristics difficult or impossible to put into categories?

Extend Your Knowledge

3. Choose a human characteristic that is not mentioned in this Topic and write a short paragraph explaining why it occurs in some individuals.

4. Reflexes are behaviours that are controlled by the human nervous system. Research some examples of reflexes and design an experiment to find out if reflexes vary in human populations.

Career CONNECT

The study of genetics has allowed us to understand our world and ourselves in new ways. Today, there are many careers that relate to genetics. A partial list is provided here. Brainstorm with your classmates to add to the list. Then choose the career that most interests you and research this job. To find out about this career, you may speak with someone who does this job, or conduct research on the Internet or in the library. Write a paragraph about some of the things you would do if this were your career.

Careers in Genetics

lab technician
bioinformatics specialist
genetics counsellor
evolutionary biologist
human genetics professor
bacterial genetics researcher
legal adviser on issues in genetics
philosopher/ethics adviser
biotechnologist

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To begin your research on a career in genetics, go to the web site above. Click on Web Links to find out where to go next. Find out what kind of education you would need to follow the career you are researching. How many years of study would be needed to do this job? Present your findings to the rest of the class.

Pause& Reflect

Red-green colour blindness, the inability to identify certain shades of red and green, is a minor genetic disorder. Many others are more serious. Do you think everyone should be tested for possible genetic disorders? Do you think none should be? Think about these questions and write your thoughts about this complex issue in your Science Log.

TOPIC 4 Review

1. Is the variation in weight in human populations an example of discrete or continuous variation? Explain your answer.
2. Is human skin colour purely an inherited trait? Explain your answer.
3. **Thinking Critically** If you one day decide to have children, which of your traits are your children likely to inherit? Which of your traits are they unlikely to inherit? How do you know?
4. Describe what happens when cells divide uncontrollably.
5. Why do scientists use studies of twins to learn about human characteristics? Consider the study of the twin firefighters. What are some reasons that could explain why these two men would choose the same style of haircut and sunglasses?
6. **Thinking Critically** Evidence suggests that the tendency to develop certain cancers is genetic. How is it possible for someone who has inherited this tendency to live a long, healthy, and cancer-free life?

TOPIC 5 When Plans Change

Variation is a characteristic of life. It is an important part of ecosystems and a feature of human populations. Later in Topic 6 you will learn more about the importance of variation in adaptations. How are all of these things linked? The answer is found in the cell's nucleus. In Grade 8 Science you learned that the nucleus is the control centre of the cell and contains the genetic material. But what does the control centre do, how does it work, and what is "the genetic material"?

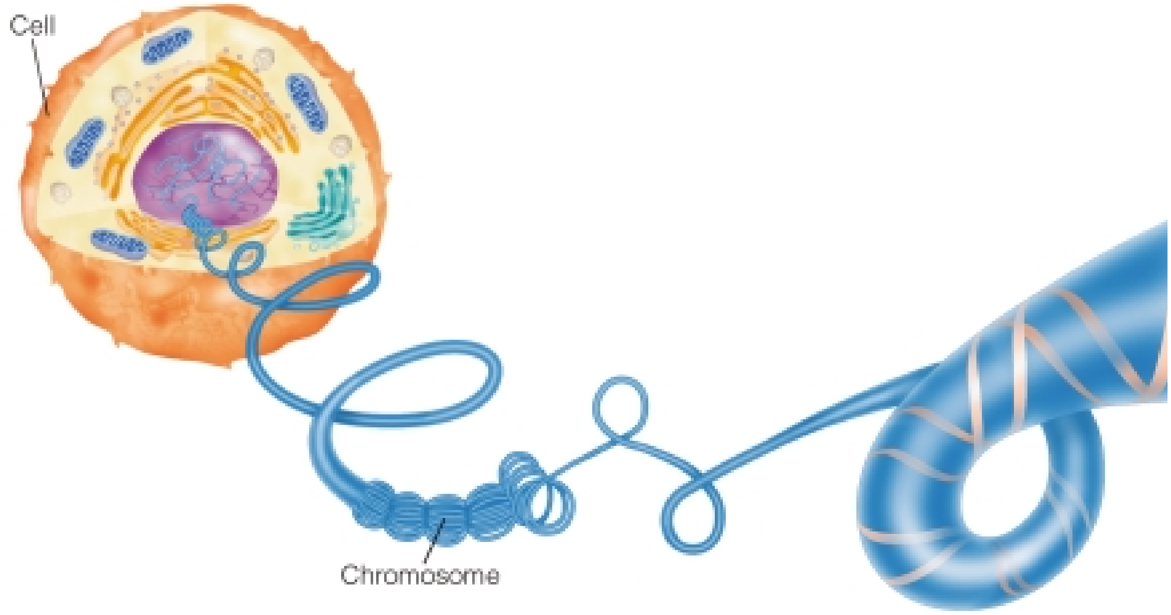


Figure 1.41 The chromosomes are found in the cell's nucleus. Chromosomes are made up of strands of DNA, the genetic material.

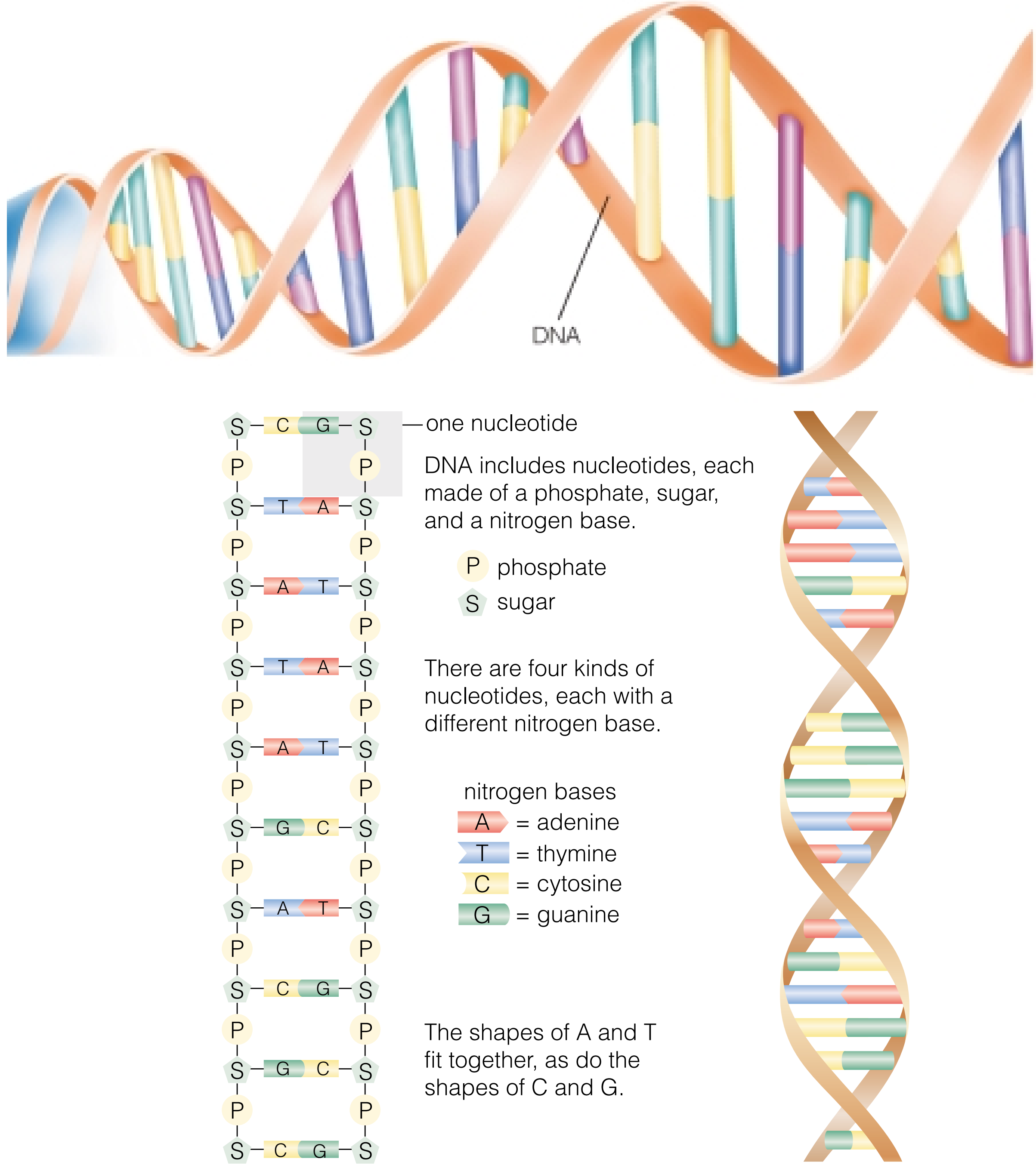
DNA: The Secret of Life

Philosophers and scientists have searched for the secret of life for thousands of years. Genetically speaking, the answer is a molecule called deoxyribonucleic acid, or **DNA**. Swedish chemist Johann Miescher collected DNA from the nuclei of certain cells in 1868. It was not until later that scientists could explain how this seemingly simple substance could carry out all of the functions of the genetic material. The genetic material had to be able to reproduce itself, move from parent to offspring, and control all the structures and functions of cells. In addition, the structure of the genetic material had to be able to explain variation within and between species.

Chromosomes, which are composed of strands of DNA, are contained in a cell's nucleus. DNA is the molecule that controls the formation of cells, the products that they release, and everything they do. DNA is also the genetic material — the plan that is passed on from one generation to another.

The Structure of DNA

Once scientists worked out the structure of DNA, they were able to explain how the molecule could do everything the genetic material had to do. Structurally a molecule of DNA has the shape of a coiled ladder. The sides of the ladder are made of alternating subunits called sugars and phosphates. The rungs of the ladder are pairs of nitrogen bases that come in four different forms: adenine (A), thymine (T), guanine (G), and cytosine (C). A forms chemical bonds with T, and C bonds to G. Figure 1.42 will help you to gain an understanding of the overall pattern of DNA.



DNA includes nucleotides, each made of a phosphate, sugar, and a nitrogen base.

There are four kinds of nucleotides, each with a different nitrogen base.

The shapes of A and T fit together, as do the shapes of C and G.

Figure 1.42 DNA is made of many thousands of nucleotides. The ladder-like structure winds like a spiral staircase.

PROBLEM-SOLVING

INVESTIGATION 1-H

SKILLCHECK

- ✹ Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Modelling DNA

Scientists James Watson and Francis Crick worked together to figure out the structure of DNA. In 1953, they presented their findings with a model made of wire and tin, as shown in the photograph. In this investigation, you will work with a partner to design and construct a three-dimensional model of a DNA molecule.

Challenge

Construct a model of DNA in three dimensions.

Materials

- Styrofoam™ chips
- modelling clay
- corks
- jelly beans
- coloured construction paper
- toothpicks
- clear adhesive tape
- scissors

Design Specifications

A. Your model must include the six colours or objects. Each colour or object will represent one of the following parts of DNA: phosphate, sugar, four nitrogen bases (A,T,C,G).

B. The nitrogen bases must be paired according to the rule: A pairs with T, and C pairs with G.

C. Your model must show the three-dimensional shape of DNA — a twisted ladder.

Plan and Construct

① With your partner, decide on what shapes and colours you will use to represent each of the parts of your DNA model. How long will your DNA model be?

② Brainstorm possible designs for your model. Make a list of your ideas.

③ Choose the best idea and sketch it. Include labels in your sketch. Then list the steps of how you will construct your model. Be specific.

④ Have your plan and sketch approved by your teacher. Then build your model.

Evaluate

1. Did your DNA model include all the parts that were outlined in your plan?
2. How did your model differ from those of other groups?
3. Did you have any problems in assembling your model? If so, how did you solve them?
4. How could you improve on your design?
5. What are some advantages of working with a partner? Did you have any difficulties? If so, what were they and how did you resolve them?

Extend Your Skills

1. Why do you think models are helpful to scientists?
2. Why do you think DNA is shaped like a twisted ladder or a double helix?

STRETCH Your Mind

As you have learned, DNA can undergo mutations. In what ways do you think the structure of DNA can be altered?

The Genetic Code

The sequence of bases, or letters, in DNA forms a code. This code is like a blueprint that controls the production of proteins in the cell. Protein molecules make up much of the structure of the cells and tissues in plants and animals. In addition, various proteins control how a cell is formed and how it functions. A section of the DNA molecule that codes for a specific protein is called a **gene**.

Figure 1.43 Airlines use a three letter code on baggage tags. There is a specific code for each airport in the world.

The Dance of the Chromosomes

Chromosomes are tightly coiled strands of DNA. Generally, each human body cell has 46 chromosomes. These chromosomes are found in 23 pairs, with one copy of each chromosome coming from each parent.

It is important that each cell in the body has a complete set of chromosomes. As a result, the formation and movement of a new set of chromosomes is an important part of cell division. There are two forms of cell division. In one case, the cell divides into two identical copies. The other form of cell division results in the formation of egg and sperm cells.

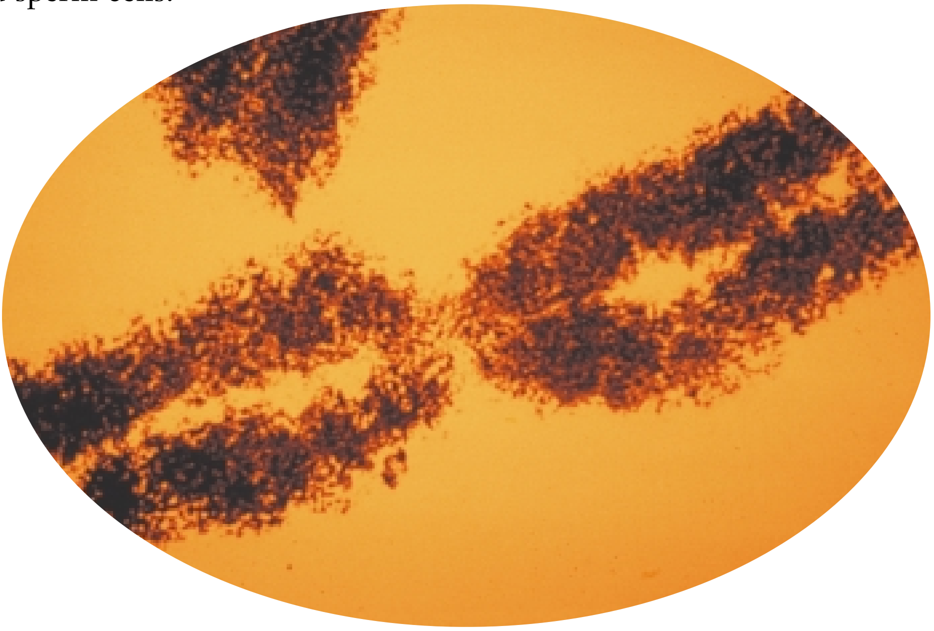


Figure 1.44 Chromosomes are formed from long strands of tightly coiled DNA.

Math CONNECT

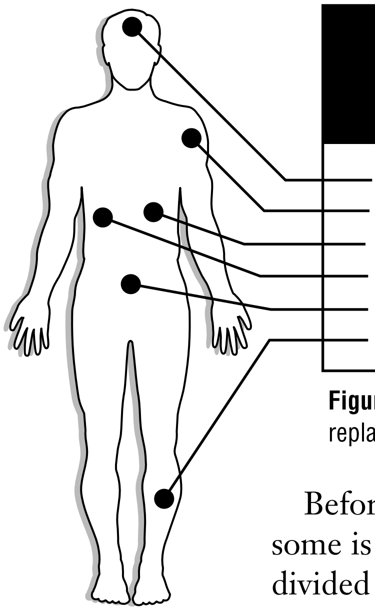
The total code for human DNA is called the human genome. The human genome contains about 3.0 x 10^9 pairs of bases. Humans have approximately 30 000 genes, and a typical gene has 3000 base pairs! Pretend for a moment that the genome is a railway track and each base pair is a railway tie. If each railway tie is 1 m from the next, how many kilometres does the track go? Given the information above, how much of the human genome is "junk" DNA that does not code for proteins?

DidYouKnow?

Dog cells have 78 chromosomes, and tomato cells have 24 chromosomes.

Normal Cell Replacement

Cells of multicellular organisms divide for growth of the organism and repair and replacement of tissues. The human body is incredibly complex and made up of many different kinds of body cells (**somatic cells**). No one knows how many cells are found in the body, but estimates range from 60 trillion to 100 million million. Some cells last a lifetime while others survive for only a few days.



LIFE SPANS OF DIFFERENT HUMAN BODY CELLS	
brain cells	30-50 years
red blood cells	120 days
stomach lining cells	2 days
liver cells	200 days
intestine lining cells	3 days
skin cells	20 days

Figure 1.45 Which cells live the longest? Which cells are replaced most often?

Before a cell divides, a copy of each chromosome is made. Then the chromosome copies are divided in a process called mitosis. This way, when the cell divides, each new cell ends up with a complete set of chromosomes. The two new cells are genetically identical to each other and to the original cell.

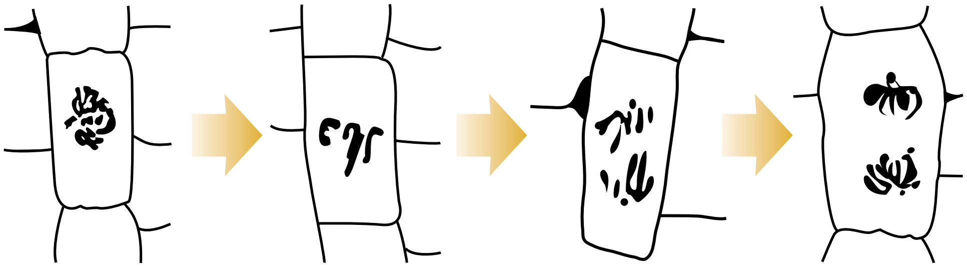


Figure 1.46 This figure shows different stages of mitosis in a cell. Before the cell divides, its chromosomes are copied. The two sets of chromosomes are then divided between the two new cells.

STRETCH Your Mind

One part of the body in which growth can easily be seen is the bones. Joy's father kept a record of her height from the time she was born until she was eight years old. When do you think cell division occurred most rapidly in Joy's skeleton? (Hint: Draw a line graph using the record of Joy's height, given below.)

Year	Height (cm)
birth	42
1	50
2	86
3	92
4	104
5	112
6	118
7	124
8	128

Pause& Reflect

Scientists are now able to grow certain body tissues outside of the human body. If researchers could create entire body organs this way, these organs could be used in people whose own organs are injured or unhealthy. Do you think it is a good idea to develop human body organs in this way? Write about the possible benefits and drawbacks of this method in your Science Log.

Sex Cells and Genetic Variation

Which type of human cell has only 23 chromosomes? These cells are the sex cells or gametes — the sperm and eggs. Only when an egg and sperm join to form a zygote does the new cell have a complete set of chromosomes. Meiosis, the process of forming the gametes, begins in the same way as the division of somatic cells. Prior to cell division, each chromosome is copied. The major difference between the two processes is that to form sex cells, cell division occurs two times. The final result is that the gametes have only half the original number of chromosomes. In humans this means that each sperm or egg has only 23 chromosomes. The process of randomly dividing 23 pairs of chromosomes in half creates the possibility of 8.4 million (2^{23}) different combinations of chromosomes! Any one of these combinations may be passed on to a gamete. In the zygote, chromosomes from two parents are combined. As a result, sexual reproduction increases variation within a species.

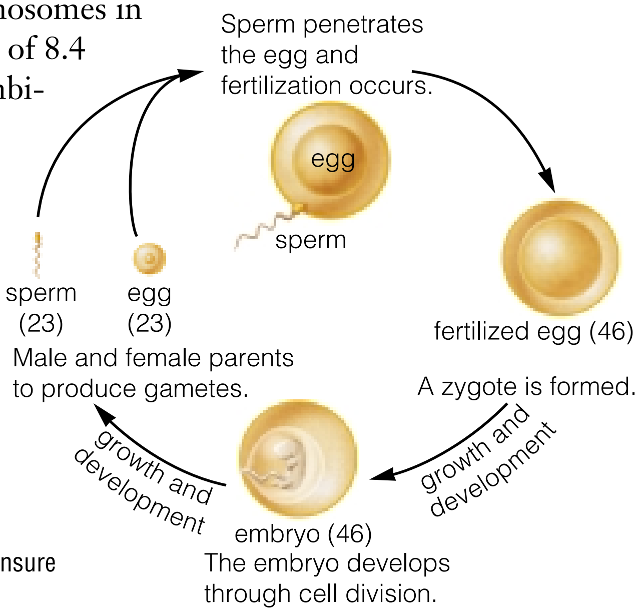
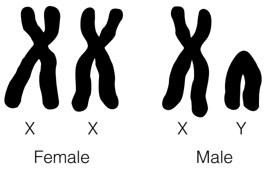

Sperm penetrates the egg and fertilization occurs.
egg
sperm
sperm (23)
egg (23)
Male and female parents to produce gametes.
fertilized egg (46)
A zygote is formed.
growth and development
growth and development
embryo (46)
The embryo develops through cell division.

Figure 1.47 How does this cycle ensure variation in offspring?

DidYouKnow?

There are two sex chromosomes: the large X chromosome and the smaller Y chromosome. Females have two X chromosomes, while males have an X and a Y chromosome. When females form eggs, each egg will get one of the X chromosomes. However, when males form sperm, half of the sperm cells will get an X chromosome while the other half will get a Y chromosome. This means that the sex of the offspring depends on which sperm fertilizes the egg. Gender is another example of variation.



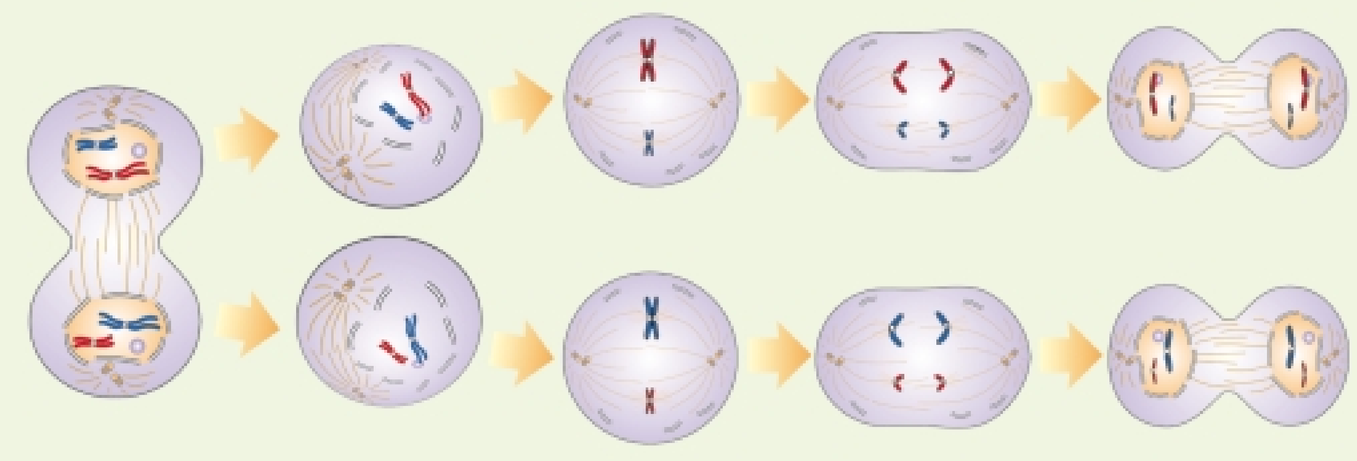


Figure 1.48 In the formation of the gametes, cell division occurs twice. Each gamete ends up with half of the original number of chromosomes.

Off the Wall

In 1991, scientists discovered that the tips of chromosomes in cells become shorter each time the cell reproduces. After about 50 replications, certain cell types stop replicating. This may be what aging really is — the inability to replace old, worn-out, or damaged cells.

The Benefits of Variation

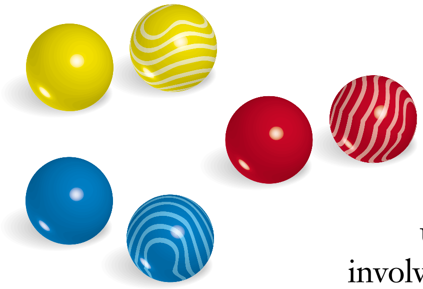


Figure 1.49 How many ways can you divide these marbles in two groups so that you have all three colours of marbles in each group? Every different combination is a form of variation — much like different combinations of chromosomes.

No individual plant or animal lives forever. Plants and animals exist today because their ancestors reproduced, either sexually or asexually. Remember that asexual reproduction requires only a single cell, such as a bacterium, to divide by binary fission. This process allows an organism to produce many offspring, usually in a short period of time. Because only one individual is involved in reproduction, the offspring are genetically the same as the parent. In contrast, in sexual reproduction, the gametes of two individuals form a zygote. Sexual reproduction requires more energy than asexual reproduction. As a result, fewer offspring are produced. However, genetic information from two parents is passed on to the offspring.

Both methods of reproduction produce more individuals of the same species, but which is better for offspring survival? The answer depends in part on an organism's environment. A change such as bad weather, disease, or inadequate food can stress organisms in a population. However, if conditions vary, even an environmental catastrophe may leave some survivors. You will see how variation in a population can be beneficial in the following activity.

Find Out ACTIVITY

Survival: The Ultimate Advantage

Aphids, a common garden pest, reproduce asexually during the summer. In late summer, they reproduce sexually and the females lay eggs, which hatch after the winter. If a species of aphid were developed that could no longer reproduce sexually, what would be the effect on the survival of this aphid species?

Materials

paper
pencils

Procedure

1. Use four shapes to represent the types of individuals in the population: squares, triangles, circles, and ovals. Draw the four shapes on a piece of paper.
2. Record the outcome of each environmental change described below.
   - **(a)** The first summer provides enough food for one season of asexual reproduction. Most of the aphids survive long enough to reproduce.
   - **(b)** The second summer is unusually cold. All of the squares die before they reproduce.
   - **(c)** The third summer is mild and most of the aphids survive long enough to reproduce.
   - **(d)** A fungus in the fourth summer kills all the ovals.
3. Begin again with the original shapes. Repeat step 2, but assume the aphids can reproduce sexually. Model the potential outcome of sexual reproduction by showing the new variations each possible pairing may produce. List all possible pairings, for example, oval/oval; oval/circle.

What Did You Find Out? Analyzing and Interpreting

Consider the impact of both sexual and asexual reproduction on the population. Describe the makeup of the population after each environmental change. Does the population become more varied or less varied? Is sexual reproduction more adventageous? Why?

Technology and Variation

Figure 1.50 This is Willow the goat, Canada's first transgenic livestock animal, born in August 1998.

In the last 30 years scientists have learned how to move pieces of DNA from one cell to another, a technique called **genetic engineering**. This has allowed scientists to move genes from one organism to another and even to move desirable characteristics from one species to another. However, using these methods, also called **biotechnologies**, raises many questions. Does biotechnology "tamper with nature"? Are there unknown harms to the environment, people, or other organisms that come with specific biotechnologies? What new opportunities and ways of solving problems will advances in science bring?

Biotechnology in Medicine

One of the first uses of modern biotechnology was to move the human gene for insulin into bacteria. The introduction of the human gene allowed the bacteria to produce insulin as a waste product. This breakthrough has allowed us to produce human insulin in large quantities. This is important for diabetics who used to depend on insulin from pigs or cattle to treat their condition.

Table 1.1 Some Common Human Proteins Made Using Transgenic Animals

Product	Use	Animal
human lactoferrin	a good source of iron for babies	cow
antitrypsin	a compound used to treat an inherited form of emphysema	sheep
factor VIII and IX	blood-clotting factors used to treat hemophilia	sheep
human protein C	used to treat blood clots	pig

Bacterial cells cannot make large, complex proteins such as the ones listed in Table 1.1. Making these proteins requires a number of steps that can occur only in the cells of a multicellular organism. However, animals can also be given human genes. Genetically modified, or **transgenic**, animals are produced by adding human genes to the fertilized eggs of the animal. Offspring that develop from the zygote grow up with a human gene. The ability to produce human proteins can then be inherited by the offspring of the transgenic animal.

An advantage of using mammals is that the proteins can be collected in the mammal's milk and then purified. This means the animal does not have to be killed to obtain the proteins.

Word CONNECT

Most new discoveries are protected by agreements called *patents*. What is a patent? Why do you think patenting a newly "invented" life form, such as a bacterium that breaks down oil, or an herbicide-resistant wheat is controversial?

Pause& Reflect

Scientists have created an "EnviroPig" — a pig that produces environmentally friendly waste for manure. The pig was created by inserting bacterial genes for degrading phosphate, an unwanted chemical, into the pig's genome. What are the pros and cons of deciding to use this approach? What else could be done to produce manure that is better for the environment? Are there any ill effects – for the pig and the environment? In your Science Log, write what you would want to find out about this procedure before the EnviroPig goes to market.

Biotechnology in Food Production

Genetic engineering has become an important part of producing food. With the ongoing decline in natural fish stocks in oceans and lakes, fish farming or **aquaculture** is becoming an increasingly important method of fish production. Scientists have added genes for disease resistance to some varieties of fish. Growth hormone genes have also been introduced into fish eggs to increase the size and growth rate of the fish.

Researchers at Memorial University in Newfoundland have added an "antifreeze" gene into Atlantic salmon and halibut. The gene comes from a species of Arctic flatfish. It produces a protein that prevents the fish's blood from freezing, thereby allowing Canadian fish farmers to operate in winter. Some scientists are concerned that the escape of transgenic fish would adversely affect natural populations. For instance, natural populations of fish may not be able to compete with transgenic varieties. What are some other possible outcomes (positive and negative) of farming transgenic fish?

Off the Wall

One problem in genetic engineering is transferring engineered DNA into a host cell. Most often viruses have been used as "transporters" or "vectors." Another method uses a "gene gun," which fires microscopic metallic particles coated with engineered DNA into a host cell.

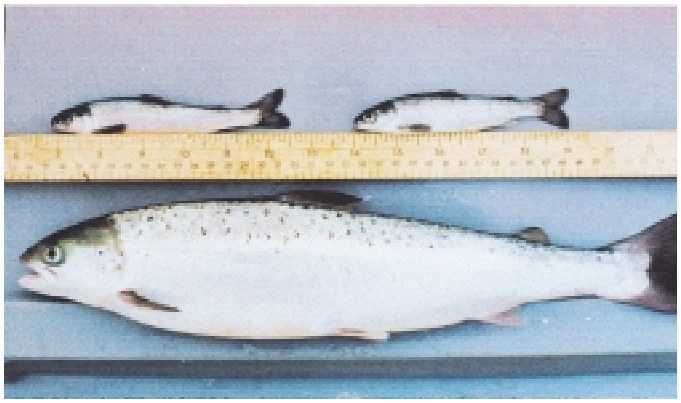


Figure 1.51 Salmon that are bioengineered to contain a gene for rapid growth can grow four to six times larger than salmon without the gene.

A Cost-Effective Crop

Crops such as wheat, corn, tomatoes, and potatoes are genetically altered for a variety of reasons. Most genetically engineered crops in Canada have been altered to be tolerant of herbicides. Since these crops are not killed by certain herbicides, farmers can use high concentrations of some herbicides, but use them less often. The results are lower costs and fewer weeds.

In the past, farmers grew plants and raised animals that survived well in local climates and soils. The result was that many different varieties of crops were used throughout the country. Now bioengineered varieties are so cost-effective that they are used across Canada. However, the widespread use of monocultures of the new varieties creates a potential problem. Even though the addition of genes to plants and animals artificially increases variation within these species, monocultures lack diversity. As a result, a single pest or disease could destroy the crops. Plant diseases that are now local problems could someday threaten the country's food supply.

Figure 1.52 Researchers experiment with putting "antifreeze" genes into salmon eggs.

DECISION-MAKING

INVESTIGATION 1-I

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Genetically Engineered Foods

Think About It

Tomatoes have a relatively short shelf life. The tomatoes that you buy in the supermarkets are nearly always harvested before they are ripe. Thus, they arrive in stores before they have begun to deteriorate. However, tomatoes that are harvested early do not have the same delicious taste as vine-ripened ones.

In the 1990s, scientists had genetically engineered tomatoes to have a longer shelf life. However, many people were concerned about the sale of genetically modified foods, especially those not labelled as such. Despite the controversy, scientists continue to develop different tomatoes that are slower to ripen, more nutritious, insect-resistant, and even salt-tolerant.

How Can Science Help?

A good understanding of how genes work and which genes are responsible for specific traits is needed in order to engineer a safe and desirable new food. Scientists then test new crop varieties for possible toxins and allergens (compounds that cause allergic reactions) as well as nutritional quality. In addition, scientists sometimes monitor the effect of genetically altered food crops on the environment.

Procedure

① As a group, choose one genetically modified food to investigate. You may have to do some background reading before choosing a topic. Find out what makes this food controversial.

② What will you need to find out in order to decide whether or not the genetically modified food should be placed or kept on the market?

In your group, brainstorm a list of questions that you will need to answer. Assign the duty of writing down these questions to one member in your group.

③ Research your questions using the Internet or library. If the information to answer your questions is not available, simply make a note of this.

④ As a group, compile the information you have gathered. If your investigation led you to more questions that you think should be answered, make a note of these questions.

⑤ Discuss with your group whether or not you have enough information to make a decision about the genetically modified food. Discuss what else you will need to know before a final decision can be made.

Analyze

1. Were you able to answer all of the questions on your list? How many questions were left unanswered?

2. Suppose you are part of a special committee to advise Health Canada on whether or not to accept the genetically modified food into the marketplace. What would you suggest to Health Canada as the next step in the decision-making process?

3. Did the members in your group pose different questions? Did you come up with more questions to investigate as a group than you would have if you had completed the investigation on your own?

Skill FOCUS

For tips on societal decision making, turn to Skill Focus 8.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

By understanding more about the genetic code, scientists hope to someday prevent or cure genetic diseases. To find out about the Human Genome Project, the international effort to determine the entire genetic code, go to the web site above, and click on Web Links to find out where to go next. Write a short newspaper article explaining what the Human Genome Project has achieved thus far. Also discuss at least one of the issues this project has raised.

Cool Tools

Did you know that your DNA has a distinct pattern called a DNA fingerprint? The same is true of DNA from other organisms. To view a person's DNA fingerprint, scientists must first extract DNA from human cell samples. The DNA is then cut into tiny pieces and separated on a gel. Using special stains, scientists are able to examine the pattern, or fingerprint, made by the pieces of DNA. This method can be used to identify people or recognize genes linked to certain diseases. Taxonomists use DNA fingerprints to learn about relationships between different organisms.

Pause& Reflect

Imagine that you are a genetic engineer. Propose an idea for a genetically modified fruit or vegetable that most of us eat. Write a paragraph in your Science Log explaining why you think scientists should look for a gene to alter that crop. Also discuss any potential effects of the modified crop on the environment or human health.

TOPIC 5 Review

1. In what way is DNA a code?
2. **Apply** An organism has five pairs of chromosomes. Answer the following questions.
   - (a) One of the organism's body cells divides. How many cells are formed? How many chromosomes does each new cell have?
   - (b) How many chromosomes are in each sperm cell?
3. **Thinking Critically** Explain why the body cells of all organisms that reproduce sexually have even numbers of chromosomes.
4. What is the main value of variation?
5. What form of reproduction favours variation? Explain why by referring to DNA.
6. **Thinking Critically** Is variation always an advantage? Explain.
7. **Thinking Critically** In what ways can transgenic organisms be used?
8. Biotechnology is very important in agriculture and medicine. What are some of the reasons the use of biotechnology is controversial? Explain using specific examples.

Wrap-up TOPICS 3-5

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

heritable
reproductive strategy
asexual reproduction
binary fission
spore
zoospore
meristem
clone
budding
sexual reproduction
zygospore
bacterial conjugation
zygote
pistil
stamen
ovule
pollen tube
embryo
cotyledon
self-pollination
cross-pollination
genetics
continuous variation
discrete variation
dominant trait
recessive trait
mutation
mutagen
DNA
chromosome
gene
somatic cells
genetic engineering
biotechnology
transgenic
aquaculture

Reviewing Key Terms

1. For each pair of terms below, explain what they have in common and how they differ. (3)

(a) pistil and stamen

(b) angiosperm and gymnosperm

(c) seed and spore

2. What is the difference between a dominant and a recessive trait? (4)

3. Describe three methods of reproduction used by plants. (3)

4. What is a heritable trait? (3, 4)

5. What molecule controls cell function, and is it also the genetic material? (5)

6. What term is used to describe an animal whose genes have been altered using biotechnology? (5)

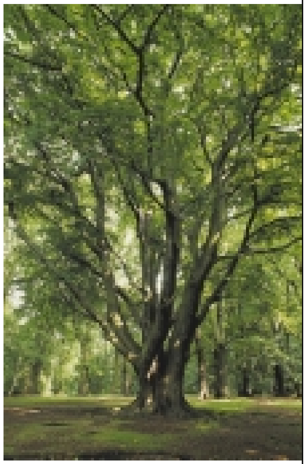
Understanding Key Concepts

7. Name three organisms that can reproduce asexually. How does reproduction differ in each case? (3)

8. What is produced immediately following the union of egg and sperm? What happens after that? (3)

9. **Apply** A beech tree has small green flowers. Explain why it is unlikely that beech flowers would be pollinated by insects. Suggest the most likely method of pollination. (3)

10. What is the importance or significance of mutations? (4)



beech tree

11. **Apply** State some of the advantages of internal over external fertilization in plants. (3)

12. Why are some human proteins produced by transgenic cows, sheep, or pigs rather than bacteria? (5)

13. It is estimated that every human carries between five and eight harmful genes. Why do you think that more people are not born with inherited diseases? (5)

14. **Thinking Critically** Why do you think that internal fertilization is associated with a higher success rate than external fertilization of eggs? What are some of the risks involved in fertilization? (3)

TOPIC 6 The Best Selection

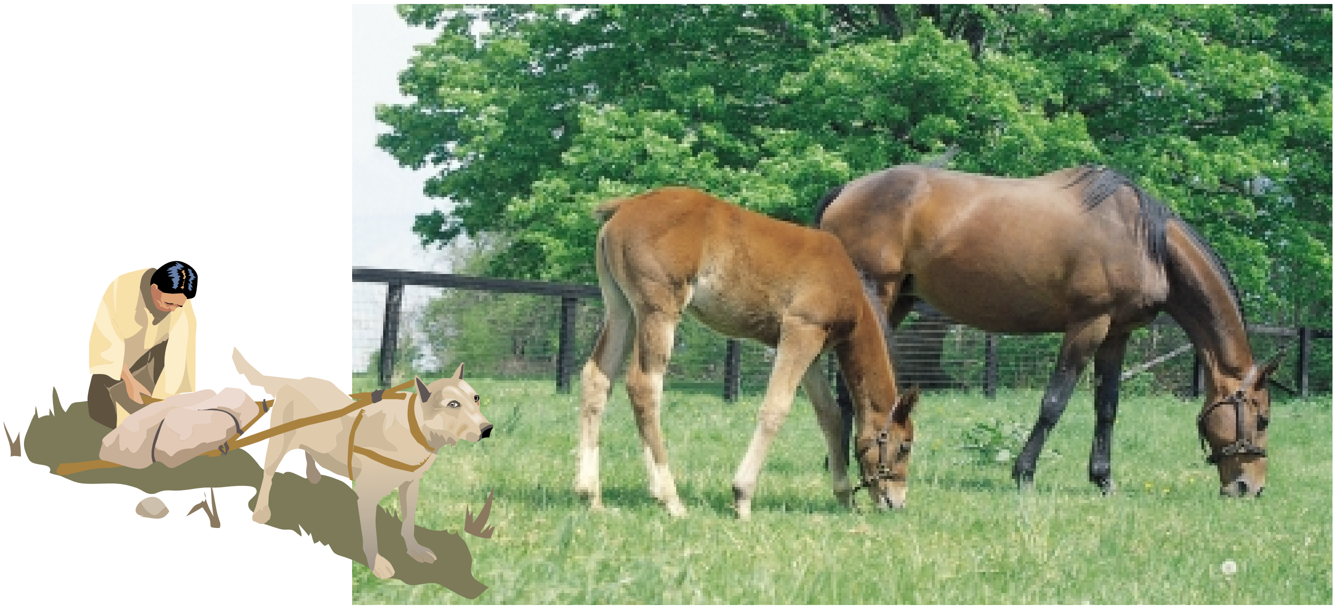


Figure 1.53 Domestic animals have been bred to help us with various tasks. Canada's Aboriginal people once relied on dogs to carry loads. Items were packed onto travois, triangular wooden frames that the dogs would drag. After the horse was reintroduced into North America, people used horses to pull larger travois.

Do you have a cat or dog at home? Do you own a pet rabbit? **Domestic** animals have had a long history of living with people. Cats and dogs are ideal living companions. They share our houses, eat our food, and sleep in our beds.

There are other domestic animals that are important to us. Do you drink milk or eat cheese or yogurt? Do you eat eggs or meat? Where did these animals come from, and why do they meet our needs so well? The distant ancestors of these animals were wild. Our own ancestors captured them, and over time, shaped these animals into the ones we know today.

In the last Topic you saw how biotechnology can be used to create animals and plants with favourable traits. People have used breeding, or **artificial selection**, for thousands of years, to produce domestic plants and animals with particular characteristics. Farmers bred dairy cows that produced the most milk. In other cases, farmers selected the best beef cattle. Sheep were bred based on the quality of their wool or meat. By breeding animals with the most desirable qualities, farmers were able to manipulate the characteristics of domestic animals over a number of generations.

Pause& Reflect

How do wildflowers found around Alberta differ from cultivated flowers grown in gardens? Do you think cultivated flowers would survive unattended in the wild? Record your thoughts in your Science Log.

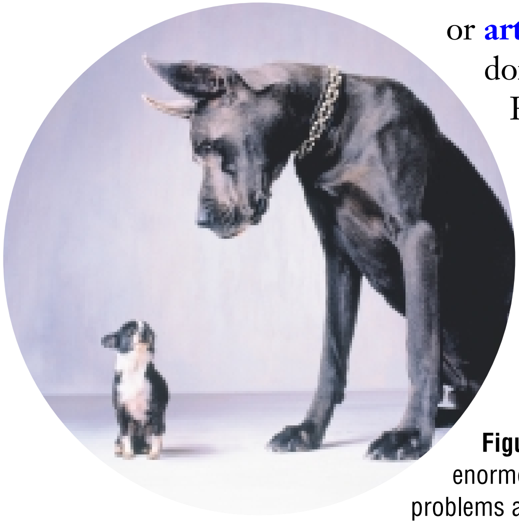
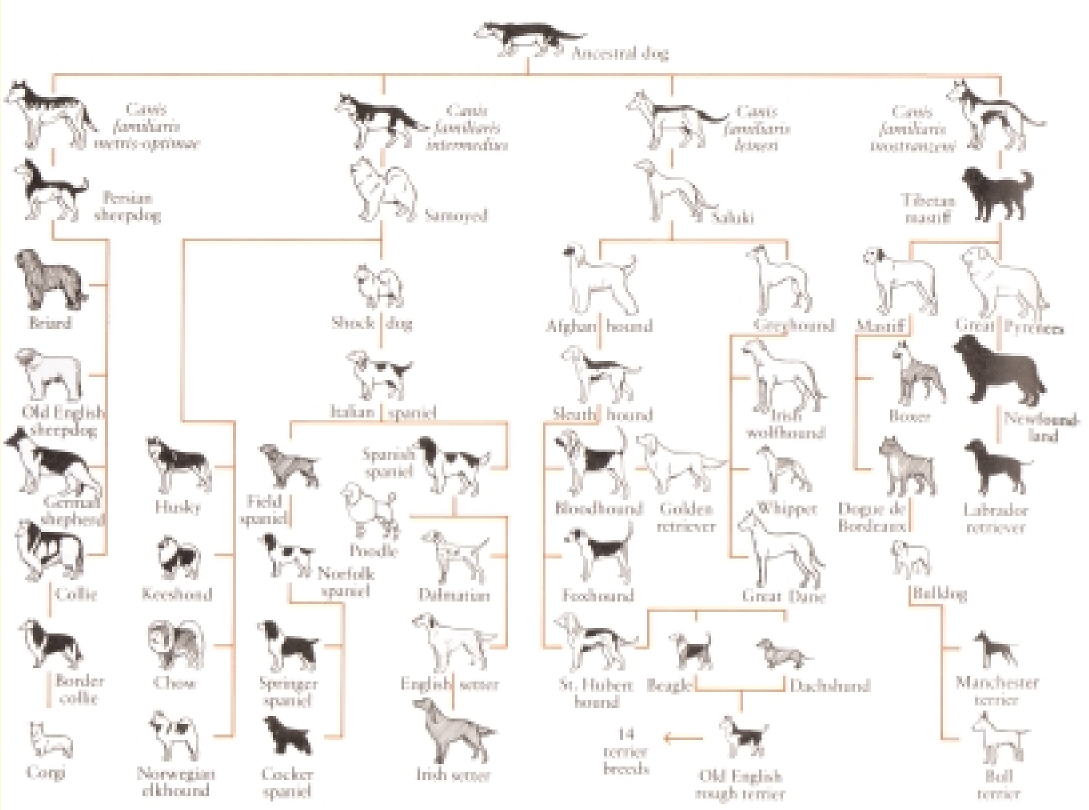


Figure 1.54 Distinctive dog breeds, such as this tiny Chihuahua and enormous Great Dane, have been produced through selective breeding. Health problems are common in purebred animals. Why do you think this is so?

Find Out **ACTIVITY**

Why Are There So Many Different Kinds of Dogs?

Archaeological finds prove that dogs have been domesticated for more than 14 000 years. There are over 160 breeds of dog recognized by the Canadian Kennel Club. There are also countless combinations of these breeds called mutts, mongrels, or mixed-breeds.



Procedure

The chart above shows that all of today's dog breeds came from one ancestral species. Use the chart to trace how so much variation came about.

What Did You Find Out? ✷ Analyzing and Interpreting

1. For what purpose was the Tibetan mastiff bred? What characteristics do you think the breeders were looking for?
2. Many of these dogs were bred to help in hunting. Which specific characteristics were bred for in:
   (a) hounds?
   (b) terriers?
   (c) setters and spaniels?
3. Which dogs were bred for protection?
4. How would you go about breeding a dog that would make a good house pet? What characteristics would you look for?

Word CONNECT

Have you ever heard of *beefalo*? Beefalo are a cross between bison and domestic cattle. Unlike domestic cattle, beefalo have thick fur, which protects them from cold temperatures. Another advantage of beefalo is that the meat is low in fat and cholesterol. If you could develop a cross-breed, what would it be? Describe this new breed's characteristics and give it a name.

Artificial Selection in Agriculture

Our hunter-gatherer ancestors began planting seeds in order to have a reliable source of food. Wheat and barley, members of the grass family, were among the first plants that were grown for food. Archaeologists have found samples of these plants in the sites of some of the oldest settlements in the Middle East. Although 80 different plants were domesticated during prehistoric times, today only a few make up the majority of the world's food supply. Wheat and rice alone provide 40% of our food energy.

The science of plant breeding is an important part of agriculture. By choosing individual plants with desirable traits, scientists use **selective breeding** to bring the positive characteristics of two different varieties together. Selective breeding was used to create specific varieties of Canada Western Red Spring Wheat. Wheat flour from this class of wheat is commonly used to make pan bread. Researchers have developed varieties that produce high quantities of flour that is high in protein. In contrast, Canadian Western Amber Durum wheat flour is good for making pasta. One new variety of this wheat has improved cooking qualities and a pleasant yellow colour. Researchers stationed throughout the country work to find out what kind of wheat will grow the best in their region. Some wheat varieties have been bred to mature faster than others or resist colder temperatures and early frost. Others are resistant to insects and diseases. By breeding plants that produce good-quality flour with plants adapted to specific locales, researchers have developed valuable crop plants.

STRETCH Your Mind

Organism	Energy (kJ/m²/year)
wheat cereal	3400
rice or rice cereal	5200
carrots	3400
milk	1800
eggs	840
beef (feedlot)	550

This table lists the average amount of energy, in kilojoules (kJ) per square metre of land per year, in different organisms that people use for food. Assume that 800 kJ of each organism is consumed in one meal. Team up with another student to calculate the area needed to produce 800 kJ of food energy from wheat and 800 kJ from beef in one year.

Figure 1.55 Canada is one of the major suppliers of wheat to the world. We grow about 20 billion tonnes of wheat each year, and export about 14 billion tonnes. Most of the wheat grown in Canada is one of two different species, but there are also many other varieties grown for specific uses.

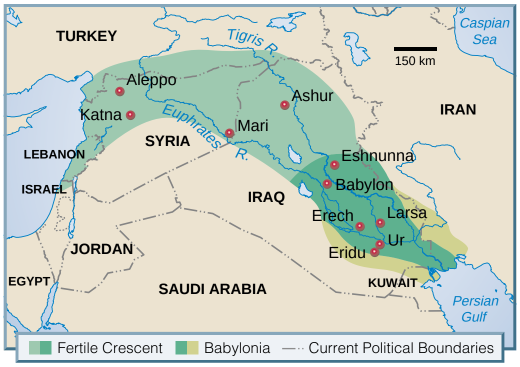
INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Conduct research on how Canadian scientists have developed cold-tolerant varieties of wheat, triticale, and rye. Go to the web site above, and click on Web Links to find out where to go next. Write a short report on how one of the crops mentioned above was developed.

DidYouKnow?

Agriculture is only about 10 000 years old. Prior to that time our ancestors were mostly hunters and gatherers. Groups of people moved from place to place hunting available game and gathering edible plants. Farming (and the ability to stay in one place) is believed to have originated in an area called the "fertile crescent." This area included the land between the Tigris and Euphrates rivers, which contained rich soil that was suitable for growing crops.



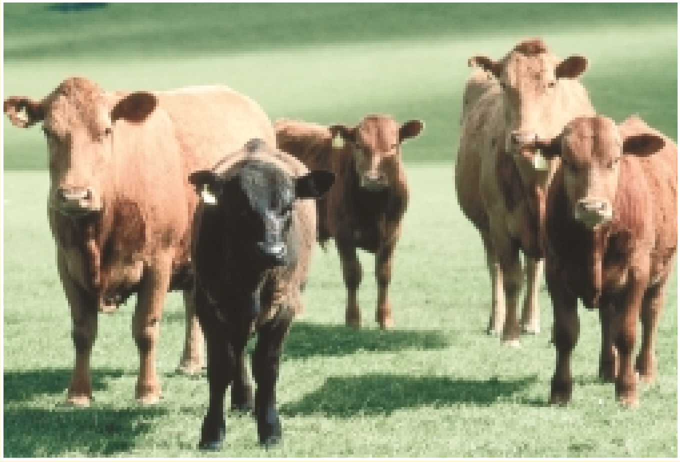
Find Out ACTIVITY

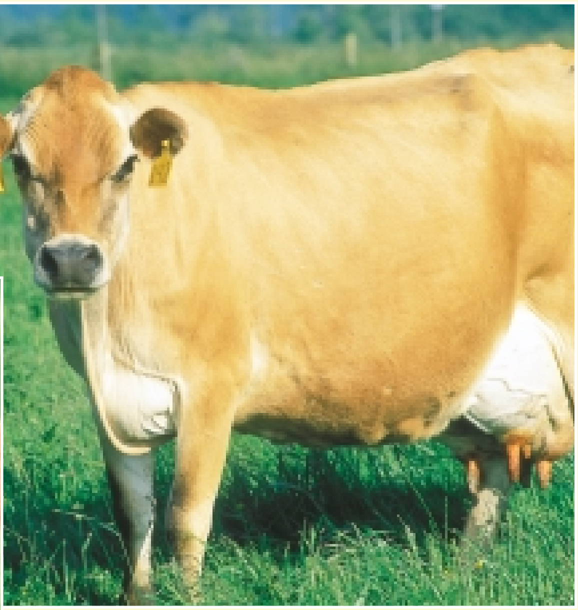
Thoughts on Food

Procedure

Examine the pictures of the different types of cattle.

beef cattle





Jersey cow

What Did You Find Out? ✴ Analyzing and Interpreting

1. What characteristics do you think were selected for in each type of cattle?
2. How does the sex of the animal affect its function?
3. Are all of the differences between the two kinds of cattle due to selective breeding? What else could account for these differences?
4. **Apply** What are some ways in which farmers can produce beef cattle with very tender meat?

Extension

5. There are many cattle breeds. Choose one to research on the Internet. Find out what traits this variety is bred for and what makes it different from other breeds. Design a one-page "Wanted" ad to describe this breed of cattle.

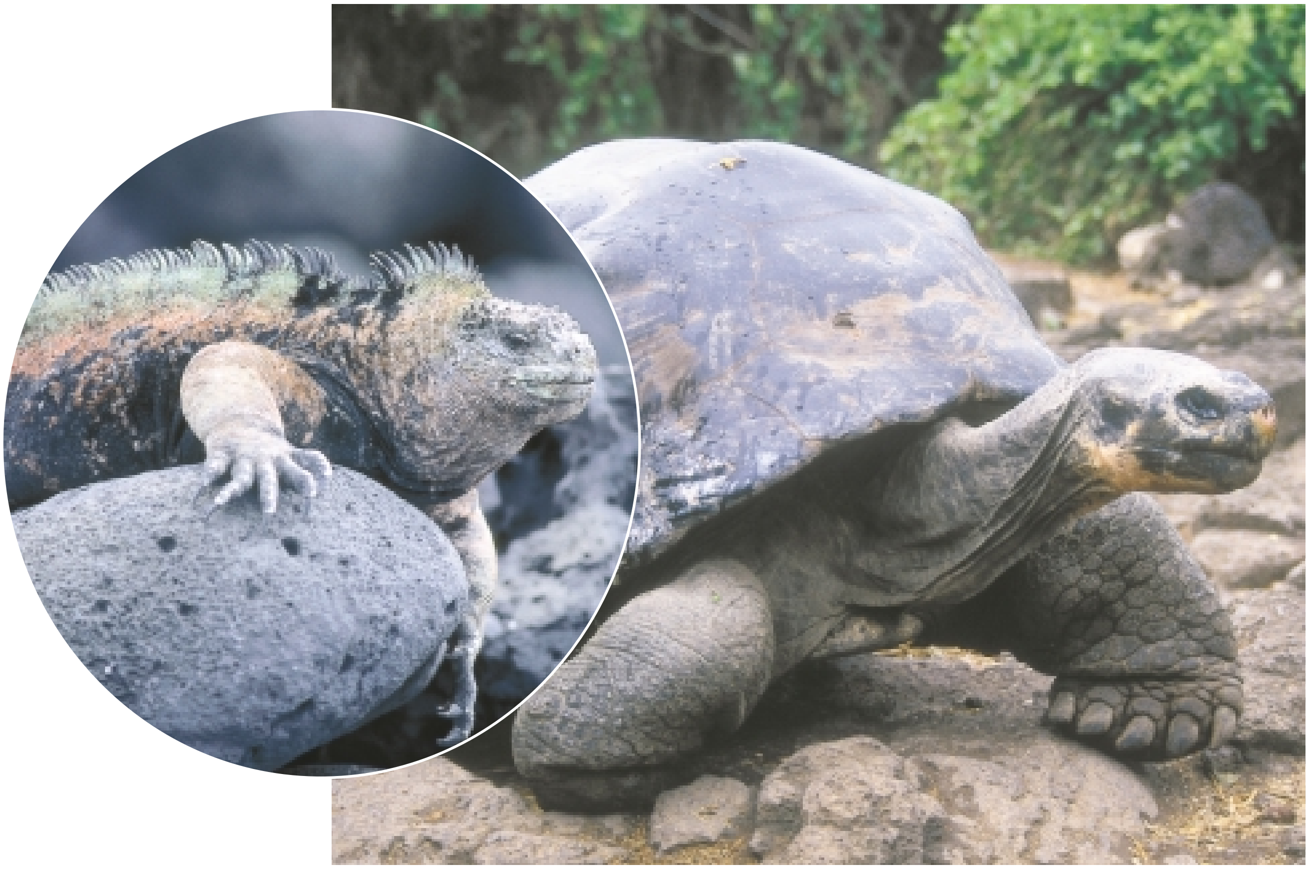


Figure 1.56 This iguana (left) and tortoise (right) are just two of the many unusual species adapted to life on the Galápagos Islands. Naturalist Charles Darwin was very interested in the biological diversity he found in this region.

Accounting for Biological Diversity

When the H.M.S. *Beagle* set sail to map the coast of South America in 1831, 22-year-old Charles Darwin was aboard. During the five-year voyage, which would eventually take the crew around the world, Darwin explored and gathered specimens from a wide variety of habitats. The Galápagos Islands off the west coast of South America were just one stop on a long voyage, but these islands would be permanently linked to Darwin and his theory. When the *Beagle* returned to England, Darwin tried to make sense of his observations. In 1859 he published his most influential book, *Origin of Species by Means of Natural Selection*.

Looking Ahead

Discuss with your group how you could monitor and record the plant life in an area before making a decision about burning a forested area.

DidYouKnow?

Charles Darwin was born into a family of doctors in 1809 in Shrewsbury, England. He was educated in his home town before being sent to university to become a doctor like his father and grandfather. However, Darwin was a terrible student and preferred to spend his time exploring the surrounding woods. He particularly disliked medical school, which he eventually quit. Convinced that Darwin would never be a success, his father sent him to study theology at Cambridge in the hope that Darwin would become a church minister. Darwin did graduate, but later signed on as "gentleman naturalist" of the H.M.S. *Beagle* — against his father's wishes.

INVESTIGATION 1-J

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Diversity in the Galápagos

Think About It

The chart below was taken from *Darwin's Journal During the Voyage of the H.M.S. "Beagle" Round the World*. The table was composed of data gathered by Darwin and other naturalists. At the time, Darwin had no explanation of the results.

The Plants of the Galápagos Islands

	Number of Plant Species			
Name of Island	**A**	**B**	**C**	**D**
James Island	71	33	38	30
Albemarle Island	46	18	26	22
Chatham Island	32	16	16	12
Charles Island	68	39	29	21

A = Total number of plant species found on this island

B = Number of plant species found in other parts of the world

C = Number of plant species found only on the Galápagos Archipelago

D = Number of plant species found only on this island

A cactus finch feeds from a cactus plant.

Analyze

1. Draw a bar graph to illustrate the data from the chart above. The data for each island should be represented using four bars (A–D).

2. Is it likely that plants found growing on the Galápagos could also be found growing where you live? Explain your thinking. How might the data above be used to support your answer?

3. Darwin found these results "striking," and pointed out that most of the islands were within sight of each other, in the same climate, and formed from the same rock. Which is the most "striking" column in the above chart? Explain your reasoning.

4. Can you offer an explanation for the data?

Extend Your Skills

5. Make a hypothesis about the more "striking" data. Devise a way of testing your hypothesis.

Skill FOCUS

For tips on drawing bar graphs turn to SkillFocus 10.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Which species are unique to the Galápagos? What threats from human activities do these species face? To answer these questions, go to the web site above, and click on Web Links to find out where to go next. Create a poster to illustrate what you have learned about one species unique to the Galápagos. You may use a computer to create your poster.

DidYouKnow?

Darwin was hesitant to publish *The Origin of Species by Means of Natural Selection*. He knew that the book would generate controversy because it attempted to explain how the process of evolution occurred. Many people in England and the rest of the world felt that this theory disagreed with their religious beliefs.

Pause& Reflect

Illustrate the evolution of an organism of your choice using models, posters, or video presentation. Organize your ideas by making notes in your Science Log.

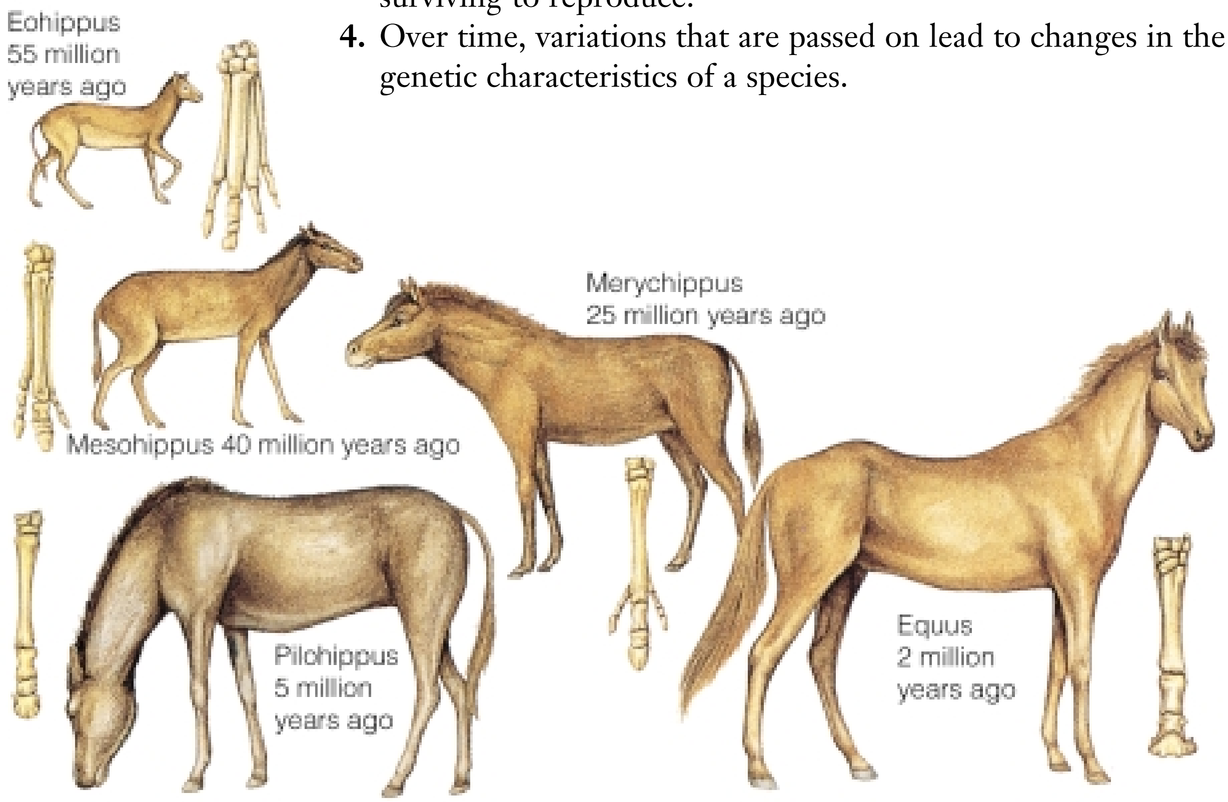
The Theory of Natural Selection

When Darwin tried to explain the diversity of life in the Galápagos, he began to think about artificial selection. He spoke with farmers and breeders about breeding cattle, horses, and other domestic animals. Darwin himself raised fancy pigeons and knew that artificial selection could produce great diversity, even within a species. Darwin developed a theory of **natural selection** to explain how a process closely related to artificial selection occurred in nature. Around the same time, biologist Alfred Wallace had also made similar conclusions. The Galápagos finches provided a good illustration of how the fittest, or best-adapted, organisms for a specific environment survived.

Figure 1.57 Pigeon fanciers have developed diverse breeds of pigeons. Some of the pigeons have been bred for racing. Other varieties come in various forms and colours.

The theory of natural selection can be summed up in four statements:

1. All organisms produce more offspring than can possibly survive.
2. There is incredible variation within each species.
3. Some of these variations increase the chances of an organism surviving to reproduce.
4. Over time, variations that are passed on lead to changes in the genetic characteristics of a species.



different from its ancestors. Horse breeders have made further changes using artificial selection.

DidYouKnow?

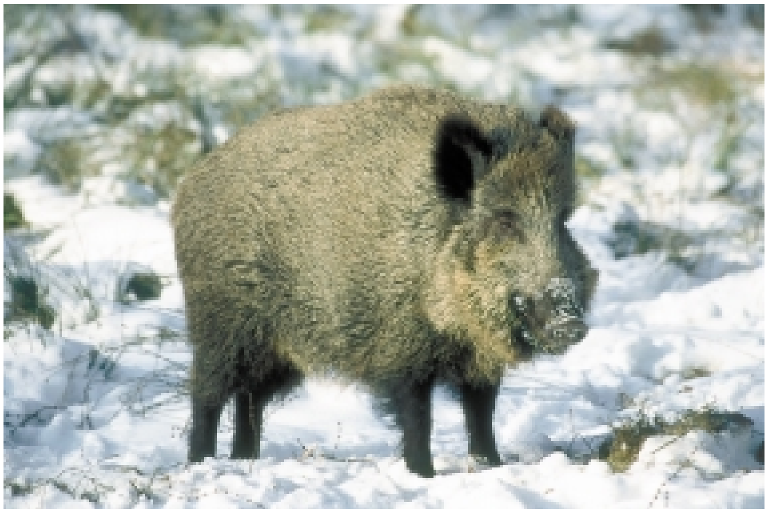
Can you spot the peppered moth? Birds are more likely to prey on the moths that are easier to see. Light-coloured peppered moths are hard to detect on tree trunks covered with white lichen. In mid nineteenth-century England, soot from industrial pollution covered the trees. The once rare, dark-coloured moths became predominant. When air became cleaner in the 1970s, the light-coloured moth became common once again. People were able to influence natural selection by causing changes in the environment.

STRETCH Your Mind

Suppose a group of children that attend a local day care have become ill with ear infections. All of the children are treated with the antibiotic methicillin. After a few days, all of the children, except one, are well. The following week, most of the children are sick again. This time, none of the children get better after taking methicillin. Why? How is this situation an "unnatural example of natural selection"?

TOPIC 6 Review

1. Which animal would you guess is the ancestor of the domestic pig? Explain your answer. (Hint: see the photo below.)
2. How do artificial and natural selection contribute to biological diversity?
3. Why does artificial selection produce changes in organisms faster than natural selection?
4. Game farms in Canada raise animals such as deer and elk. Explain how elk bred on game farms are the result of both natural and artificial selection.
5. Purebred animals are sometimes very unhealthy. For example, Great Danes often have weak hearts and Dalmations commonly become deaf.
   - (a) Would you expect to see similar health problems in wild animals? Explain your answer.
   - (b) What are the advantages and disadvantages to owning a purebred animal compared to a mixed breed?



TOPIC 7 The Sixth Extinction?

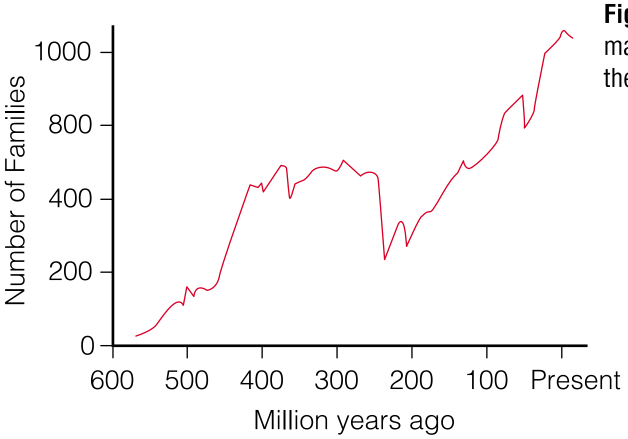
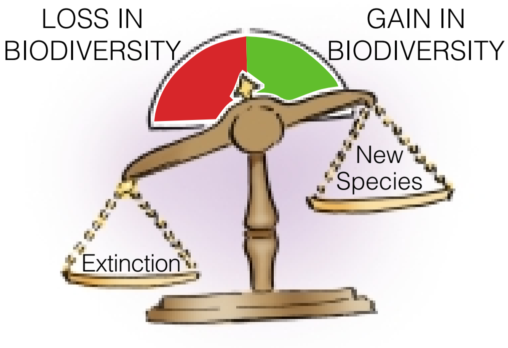


Figure 1.58 There have been five major declines in Earth's biodiversity in the past. Has another decline begun?



In the last 600 million years there have been five major declines in Earth's biodiversity. Even so, for the last 65 million years the rate at which new species were formed has been greater than the rate of extinction. Many scientists agree that the rate of extinction has been about one species per year over the history of life on the planet. Today that rate may be closer to 70 extinctions per *day*! As the rate of extinction increases, the scales are tipped toward an overall trend of decreasing biodiversity.

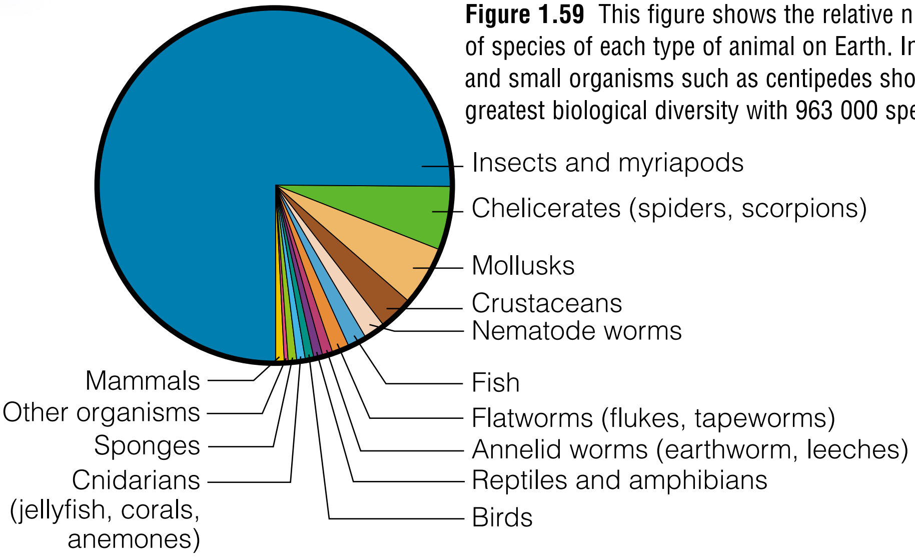


Figure 1.59 This figure shows the relative numbers of species of each type of animal on Earth. Insects and small organisms such as centipedes show the greatest biological diversity with 963 000 species!

Word CONNECT

The sao la, or *Pseudoryx nghetinhensis,* is a newly discovered mammal species. It lives in a forested region on the border of Laos and Vietnam. This shy relative of goats and cattle was unknown to Western scientists until the 1990s. However, locals are very familiar with the sao la. The sao la looks like an oryx, although these animals are unrelated. Write a note explaining why you think the sao la was given the scientific name *Pseudoryx*.

DidYouKnow?

Sixty-five million years ago dinosaurs dominated Earth. Evidence from fossils points to a complex world with many different life forms. Scientists continue to debate the cause of the dinosaurs' abrupt extinction, but the current "best guess" is that a large meteorite hit Earth off the coast of the Yucatán peninsula, Mexico. The resulting explosion hurled a massive amount of debris into the atmosphere, blocking the rays of the Sun. Without light, photosynthesis came to a halt and food chains collapsed. Other theories involve massive volcanoes or periodic changes in the world's climate. Some scientists think that the extinctions were not caused by a single event but occurred over a period of time.

Cool Tools

These scientists are studying one of Earth's biodiversity "hot spots," a tropical rain forest. There are a number of ways to measure the biological diversity of an area. In one method, a smoke bomb is used to get a sample of the insects present in the forest canopy. A biodegradable insecticide is sprayed into the upper tree canopy and the affected insects fall into plastic sheets set out below.

When scientists used this technique in the rain forests of Peru, they obtained over 43 species of ants from one application of insecticide and only one tree! This is equal to the entire ant fauna of the British Isles! Using this method, scientists have also estimated that 1 ha of Panamanian rain forest may have over 18 000 species of beetles, most of which were previously unknown to science. To date only 24 000 beetle species have been identified in all of Canada and the United States.

Human Impacts on Biodiversity

Some areas of the world support greater biological diversity than others. Heat, light, and rainfall promote the growth of plants, which leads to more complex food chains and greater biodiversity. This trend can be seen in Figure 1.60. However, the trend is not consistent. What other factors influence biological diversity?

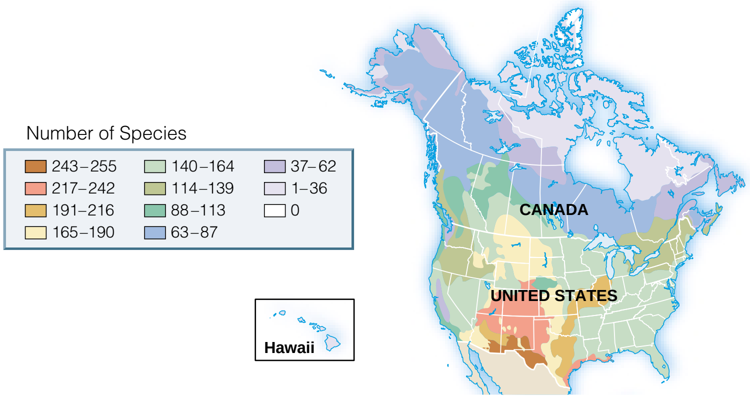


Figure 1.60 This map shows the distribution of the diversity of butterflies across Canada and the United States.

Pause & Reflect

Over time, climates change and natural disasters occur. The complex interactions between plants, animals, and their changing environments result in successful and unsuccessful species. Natural selection chooses "winners," which have adapted. As for the others, scientists estimate that 99% of all species in the history of Earth no longer exist. Today, changes in the environment caused by human activity occur so rapidly that many species do not have time to evolve and adapt. What are some changes that certain species may have trouble adapting to? Write your thoughts in your Science Log.

Did You Know?

Arctic animals such as the caribou are threatened by increasing temperatures in the region. As it becomes warmer, the caribou migrate farther north. Many scientists believe that increasing greenhouse gas concentrations from human activities are causing the warmer temperatures.

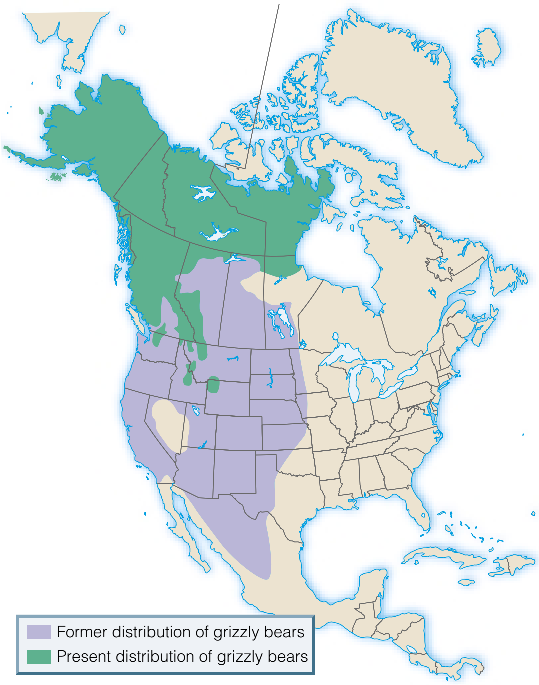
THINK & LINK

INVESTIGATION 1-K

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Where Have the Grizzlies Gone?


🟪 Former distribution of grizzly bears
🟩 Present distribution of grizzly bears

Think About It

Just 150 years ago, between 50 000 and 100 000 grizzly bears roamed western North America, from the grasslands of Saskatchewan to the coast of the Pacific Ocean and as far south as Mexico. Today, grizzlies occupy less than 2% of their original range. The disappearance of the grizzly from all of Mexico and most of the United States is an example of **extirpation**, the extinction of a species in certain locales. As settlers moved from east to west, the bear disappeared. Although many grizzly bears were killed by hunters, the reasons for the bear's rapid decline are complex. In Alberta, prior to European settlers, there were probably 6000 grizzlies spread across the province. As of 1990, there were an estimated 200 grizzly bears in the national parks and 600 on other provincial lands.

What to Do

With a partner, examine the map, and brainstorm some possible reasons to explain why grizzly bear populations have decreased.

Analyze

1. In parts of Canada and the United States it is still possible to get a licence to hunt grizzly bears. Hunters will pay $10 000 or more just for the possibility of shooting one of these bears. What are some of the reasons that grizzly bears continue to be hunted?

2. How might farming and ranching affect grizzly bear populations? (Keep in mind that grizzlies need large tracts of wilderness.) How would farmers be affected if grizzly populations increased?

3. Are there any "islands" of isolated populations of grizzlies at present? What are some possible problems for such isolated populations?

4. What do you think are some measures that could be taken to protect grizzly bears?

Extension

5. Some people feel that grizzly bears should be removed from areas where they might interfere with people's enjoyment of the wilderness. Argue for or against this statement.

Disappearing Habitats

Many people feel that the grizzly bear is a **bioindicator species**. The ability of this large carnivore to survive in an area is a measurement of human impact on the environment. Historically, one of the first effects of human interference in an ecosystem is loss of the large carnivores such as bears and wolves. Like the grizzly bear's range, that of the wolf, cougar, and wolverine have also shrunk. For this reason many people believe that the preservation of these animals goes hand in hand with the preservation of their habitats.

Figure 1.61 The range of the wolverine has shrunk significantly over time. In 1999, there were thought to be fewer than 1000 breeding wolverines in Alberta. Wolverines live in wild and remote areas and avoid human settlements.

Human Impact on Rain Forest Ecosystems

Our global population is increasing faster than ever before. New methods of farming to produce more food and better ways of preventing and treating diseases have reduced infant deaths and allowed people to live longer in many countries. The result is a larger human population that has put increased demands on the environment. In place of natural habitats, more land is being cleared for farming. The call for housing and consumer products has produced an increase in logging and mining. Altogether, these human activities have also contributed to increasing pollution.

Figure 1.62 How large a supply of materials and energy would a city such as Vancouver, British Columbia use daily? How much waste would it produce?

Math CONNECT

Tropical rain forests are being cut down at a rate of about 1% per year. Assuming this rate remains constant, if a given rain forest were 2050 km^2, how long would it take for the forest to be cut down completely?

Cool Tools

Estimating the numbers of large carnivores such as grizzlies is no easy task. A number of different methods are therefore used to study populations of grizzly bears. One way is to trap and tag or collar the bears. Each tag or collar has its own batteries and transmitter. Biologists can track the bears using radio receivers to pick up signals sent by the transmitter. More recently, Global Positioning Systems are being used to locate grizzlies. Global Positioning Systems use satellites to locate specific points on Earth. In this method, a bear's collar receives information from the satellites. The result is that the location of the bear is logged in the bear's collar. Researchers can download data from the collar remotely or by collecting the collar itself.

Pause& Reflect

If global temperatures were to rise high enough to turn lush, tropical regions into dry regions, how do you think local wildlife would be affected? Record your thoughts in your Science Log.

Find Out ACTIVITY

How High Can It Go?

How fast is the global human population increasing?

Procedure **Performing and Recording**

Draw a line graph showing the change in the human population over time using the data from the chart. Be sure to include a title and label both the horizontal (year) and vertical (population) axes.

Analyze **Analyzing and Interpreting**

1. What relationship between time and population is illustrated by your graph?
2. How can you determine what the population will be in the year 2050?
3. What factors would cause this estimate to be too low? Too high?

Year	Population (in millions)
5000 B.C.E.	50
800 B.C.E.	100
200 B.C.E.	200
1200	400
1700	800
1900	1600
1965	3200
1990	5300
2002	6100
2050	?

Skill FOCUS

For tips on extrapolating data from graphs, turn to Skill Focus 10.

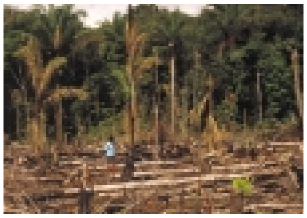


Figure 1.63 This tropical rainforest is being cleared for agriculture.

Pause& Reflect

Is the rate of population growth in Canada increasing, decreasing, or staying the same? Do Canadians have an impact on what happens to biodiversity in other countries? From where do Canadians get their pineapple and coffee? Record your thoughts on these questions in your Science Log.

The Population Explosion

The impact of population growth is not shared equally. Developing nations are often hardest hit by the population explosion, and it is in these regions that biological diversity is the most threatened. Areas in tropical rain forests are often cleared to make small farms. Some trees are used for firewood, an inexpensive source of fuel for local people. Land is also cleared to make way for cattle ranches or large pineapple or coffee plantations. The loss of even a single area of rain forest can mean the extinction of specialist organisms that depend on the forest for food or protection.The destruction of the rain forests is made more difficult to repair because the forest soil has few nutrients. In general, the nutrients accumulate in the fast-growing plants. This means that farms and plantations are usually successful for only a very short time. The lack of soil nutrients also prevents regrowth of the forest. At least for the foreseeable future, the damage already done to the rain forests is permanent. Many species have already been lost.

DidYouKnow?

Orangutans are tree-dwelling primates that live in the rain forests of Sumatra and Borneo. These fascinating animals are endangered and face a number of threats, such as the destruction of their habitat. Hunting and trapping have also reduced their numbers.

DECISION-MAKING

INVESTIGATION 1-L

SKILLCHECK

- ✹ Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

The Suffield Horses

Think About It

The National Wildlife Area at the Canadian Forces Base Suffield is home to numerous native species of plants and animals, some of which are endangered. Last century, feral horses also inhabited the Suffield prairie grasslands. The horses were a unique breed, descended from domestic horses that had been released into the wild. However, the rapidly growing population was damaging the grasslands. The fragile ecosystem was at risk, and in 1993, the horses were rounded up and adopted. This decision caused a great deal of controversy. There were good arguments on both sides.

Pros	Cons
• A unique ecosystem would be preserved. • The horses would be well taken care of by their adopted owners.	• The horses would lose their identity as a unique group. • The horses would lose their freedom. • People would no longer be able to view the horses in a natural setting.

How Can Science Help?

When animal populations grow too high, many problems can result. Scientists must investigate effects on human communities as well as natural ecosystems. In the case of the Suffield grasslands, scientists studying the ecology of the area came to realize it was one of few remaining habitats for endangered local species. Scientific observations of the landscape were key in order to assess the impact of the Suffield horses on the grasslands. The effects of the horses were easy to see: vegetation was being over-grazed and the landscape was eroding. Today, scientists continue to observe wildlife in the area and monitor it for changes in species populations.

Procedure

① Suppose a unique population of animals lives near your area. Scientists would like to know more about this group. However, the animal population is too high and is damaging the environment. Perhaps the animals carry disease, and some people have become sick. Consider what should be done in this situation.

② One alternative is to remove the animals from the area. As a class, come up with points you could make in favour of and against this decision.

③ Take a class vote to decide which side has the most convincing points.

Analyze

1. What was the most important factor in making your choice?
2. What else would you need to know in order to evaluate your decision.
3. Were there any alternatives to the issue that were overlooked? Would you have preferred one of these alternatives? Why?

Extension

4. Did the removal of the Suffield horses from the grasslands have the desired effect on the ecosystem? Research this question on the Internet.

Skill FOCUS

For tips on societal decision making, turn to Skill Focus 8.

Some Recent Extinctions

1665	Dodo, Mauritius
1852	Spectacled cormorant Russia
1883	Quagga, Africa
1914	Laughing owl, New Zealand Passenger pigeon, North America Carolina parakeet, S.E. United States
1936?	Tasmanian wolf, Tasmania, Australia
1960	Blackfin cisco, North America
1982	Banff longnose dace, Alberta, Canada

?

Human Activities and Extinction

People have not always been as aware of their impact on species survival as they are today. It is thought that the woolly mammoth was hunted to extinction some 10 000 years ago. Around 500 C.E., humans killed off most of the large animals on the island of Madagascar. The same story was repeated in Australia and New Zealand. Perhaps the most dramatic example of humans hunting an animal into extinction was recorded in eastern North America in the late nineteenth century. Hunters killed about 5 billion passenger pigeons. The passenger pigeon went from being the world's most abundant bird to extinction in less than 100 years. Today many people are concerned about conservation efforts and are trying to find ways to prevent overhunting and overfishing. On the one hand, technology can help us preseve biodiversity, as we shall see in Topic 8. On the other hand, technology has increased our ability to affect biodiversity by using up natural resources and damaging the environment.

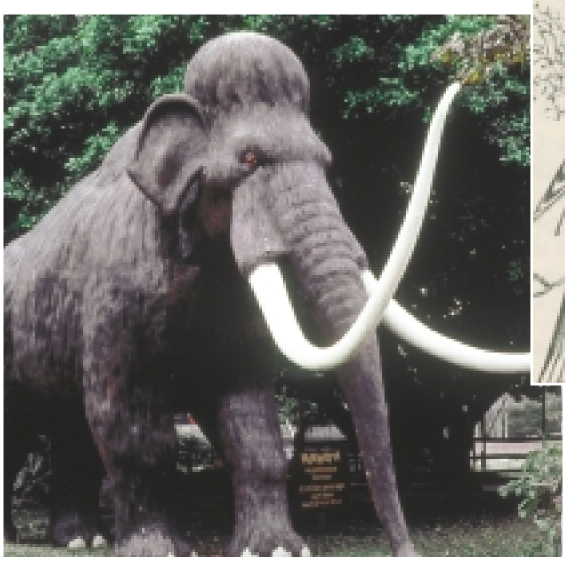


Figure 1.64 The woolly mammoth and passenger pigeon were both hunted to extinction.

Pause & Reflect

As grizzlies feed on vegetation, they spread seeds and turn over the soil, bringing nutrients to the surface. As a result, some plants grow better in areas where grizzlies have been digging. How might the loss of grizzlies from an area change the ecosystem in which they live? Write your thoughts in your Science Log.

TOPIC 7 Review

1. Name five ways in which humans have had an impact on biodiversity in your location.
2. In general, there is more biodiversity in the bird life in the tropics than in the North. Why has Hawaii lost at least 50 species of birds in the last several years? Suggest a possible explanation
3. There are more species on Earth than ever before. Why do scientists say that biological diversity is decreasing?
4. Does your daily life affect biodiversity on the planet? Explain your answer.

TOPIC 8 Pains and Gains

The idea that Earth's biological diversity is decreasing troubles many people, but what can we do to stop or even slow down the decline in biodiversity? Why should we be concerned? What actions are available and how practical are they? Biologists, governments, and ordinary citizens can all play a role in halting the decline.

The Role of Zoos in Preserving Biodiversity

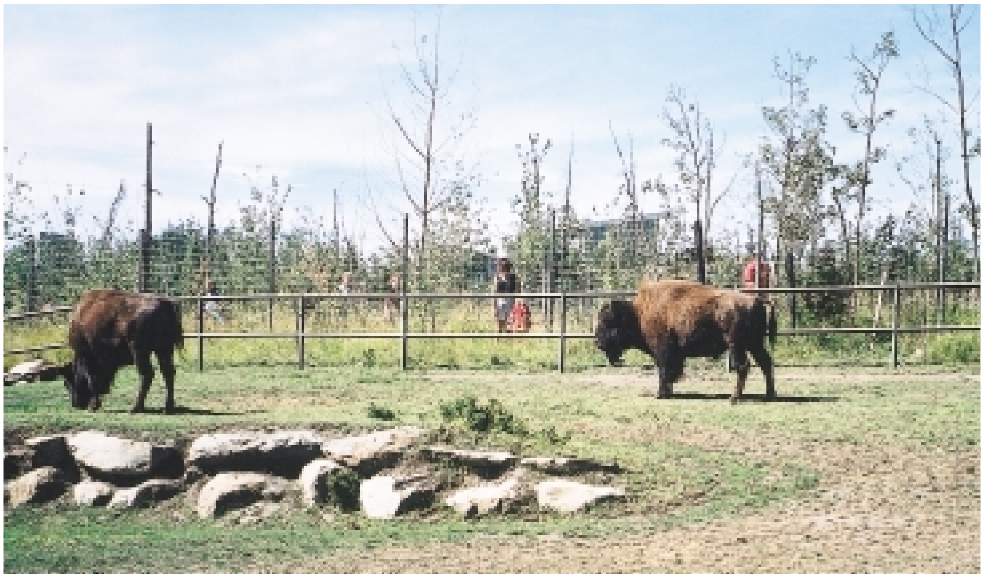


Figure 1.65 The Calgary Zoo is known as one of the finest in the world. It opened in 1929 on St. George's Island. Since then, the zoo has grown, and now exhibits 1100 animals, including endangered species such as whooping cranes and Siberian tigers. The zoo is a major tourist attraction and has thousands of visitors every year.

Zoos are more than just a place to display plants and animals from around the world. The Calgary Zoo is an educational institution that runs school programs for elementary to high school students and is visited by students from across the province. The zoo is also a part of a worldwide network that is attempting to protect and preserve endangered animals. By exchanging animals between zoos, the network hopes to maintain the genetic diversity of these species. This genetic diversity is essential to species survival. In addition, the zoo initiates and supports research on biodiversity around the world.

To many people, zoos are the only visible evidence of our attempt to maintain biological diversity. The plants and animals are a concrete reminder of the world outside our own experience. Others see zoos as the perfect answer to the problem of declining biodiversity. They argue that saving a few samples of the world's different plants and animals is sufficient. Why should we slow progress and spend money to preserve the same species in the wilderness?

Did You Know?

Zoos began as private collections of exotic animals kept by the very rich. These collections were similar to collections of stamps, coins, or fine art. They were primarily for the enjoyment of the owner. The first public zoos were opened in the early 1800s in London, Vienna, and Paris. Today there are thousands of "zoos" around the world, and they range in size and quality from large, well-run and well-funded institutions to roadside attractions.

Pause & Reflect

Sometimes it is very difficult to recreate an animal's habitat in a zoo environment. In this situation, should the animal be kept in a zoo? What if its natural environment is dwindling? Would that alter your thinking? Debate both sides of the issue with a patner or a group. Record your arguments in your Science Log.

THINK & LINK

INVESTIGATION 1-M

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

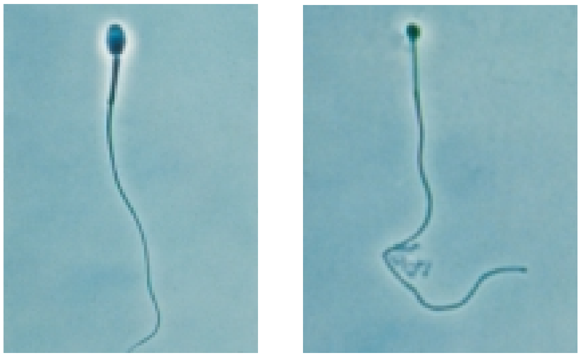
Assessing Breeding Potential

Think About It

Imagine you are assisting with a breeding program at the Calgary Zoo. The zoo already runs such a program with the Amur tiger, but is considering breeding cheetahs instead. Your job is to assess and recommend which of the two species will be the better candidate for the program by comparing sperm concentrations in each species.

What to Do

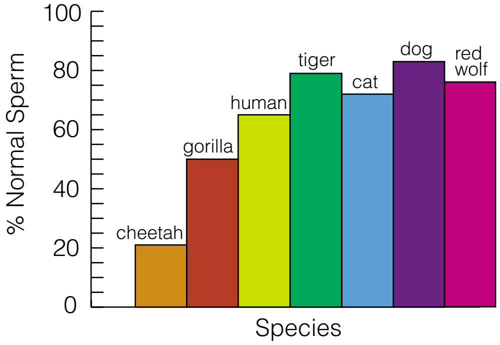
1. Compare the percentage of actively moving sperm for each animal. Record which has the highest percentage. How might this influence successful fertilization?
2. Compare the percentage of normal sperm in each cat's sample to the percentage of normal sperm for the cat's species. Is either animal above or below the normal amounts?
3. Compare the sperm concentration for each cat to the normal sperm concentration for its species. Do both animals have enough sperm to fertilize an egg?



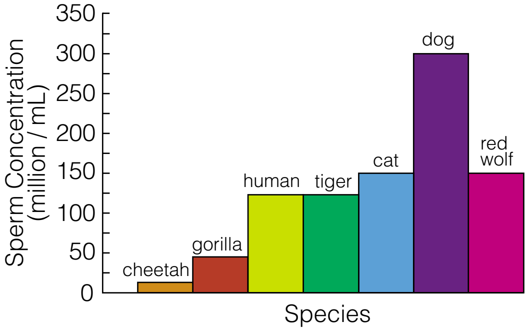
The sperm on the left is normal. The abnormal sperm shown on the right is smaller and has a crooked flagellum. Animals with normal sperm are more likely to reproduce and to have healthy offspring.

Data for Samples of Sperm Taken From Two Endangered Cats

Variable	Tiger (Tonghua)	Cheetah (Chuma)
percent sperm moving actively	95	75
percent normal sperm	80	28
sperm concentration (millions/mL)	125	5



Percent normal sperm in selected mammals



Normal sperm concentration in selected mammals

Analyze

1. Write a report recommending which animal is likely to be more successful in the breeding program. Use the results of your analysis to support your conclusion.
2. Based on your investigation, what conclusions can you draw about the relative ability of each cat to reproduce?

Preserving the Biodiversity of Plants

Seed banks are established to gather and store seeds from plants that are threatened with extinction. In some cases seed banks are run by companies that sell a wide variety of plants to gardeners and farmers. Such companies cater to individuals who want to grow something unusual or who live in specialized environments. Other seed banks are run by governments or universities for research purposes. One of the largest seed collections is in the Royal Botanic Gardens in London, England. The goal is to gather samples of 10% of the world's seed-bearing plants. The seeds are stored at –20°C, and a few seeds of each sample are germinated every ten years. It is estimated the samples will last a couple of centuries.

By collecting seeds, researchers are able to preserve the genetic diversity of many plant species. This diversity may be a useful resource in the future. Some tree planters have another method of maintaining genetic diversity in the wild. Instead of replanting areas with trees grown from seed stocks, they use seeds that have been collected straight from the forest floor.

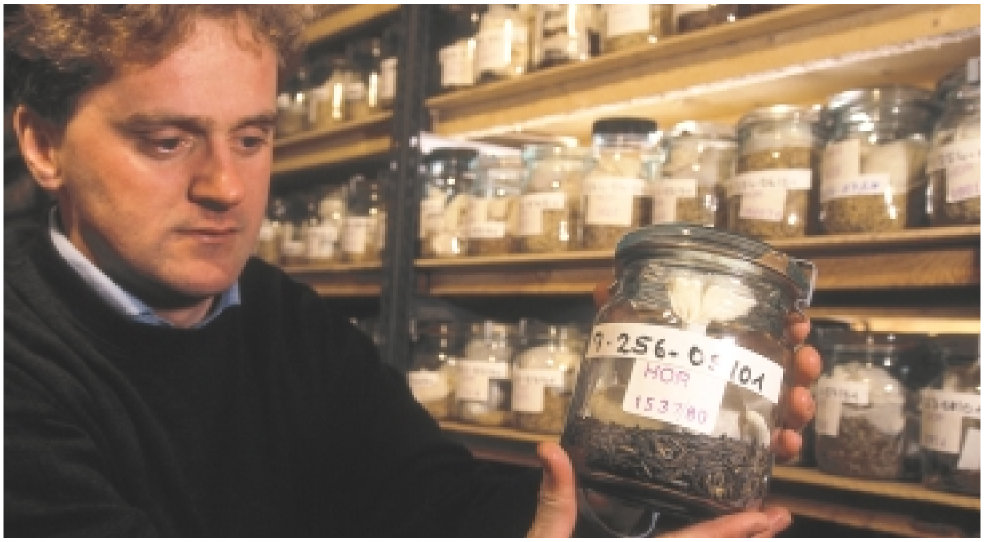


Figure 1.66 Seed banks are one way of preserving the biological diversity of plants. However, many scientists would also like to preserve plant biodiversity as it exists in natural ecosystems.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

How would you design a good quality zoo? Evaluate your sources of information based on whether or not the site is up to date, is believable, and the extent to which its claims are supported by data. Write a short (one-page) report outlining your findings and opinion. To begin your search you can visit the web site of the Calgary Zoo. Go to the web site above, and click on Web Links to find out where to go next.

Pause & Reflect

Suppose scientists have identified ten species of falcon. Five of these species are endangered and face extinction. Three of the five endangered falcon species are close genetic cousins of a falcon that is not endangered. Which of the endangered falcons should we protect? All of them? Or only the two genetically distinct falcons? Write your thoughts in your Science Log.

Figure 1.67 It is illegal to hunt leopards and cheetahs and sell their skins. Even so, some people will pay a high price for these products.

Figure 1.68 This rhinoceros is being protected from poachers by guards.

A Global Effort

The preservation of biological diversity depends on both local efforts and global co-operation. The Eastern Slopes Grizzly Bear Project is a Canadian-based study to learn how human activities affect grizzlies in and around Banff National Park. Knowledge gained from the study is being applied locally in conservation efforts. However, because of the demand for grizzly bear products outside of Canada, international co-operation is needed to conserve the grizzly bear.

Global treaties have been drawn up to protect endangered plants and animals. The 1975 Convention on International Trade of Endangered Species (CITES) is aimed at preventing endangered plants, animals, or parts of these organisms from being imported or exported. This law makes it illegal to buy or sell endangered animals such as rare birds, reptiles, or amphibians. It also makes it illegal to buy or sell animal parts such as rhino horns or elephant tusks, which are used to make jewellery, sculptures, or folk remedies. Five hundred species are identified for protection by CITES. In addition, one hundred and eighty countries have signed the 1992 Convention on Biodiversity and have agreed to set up protected areas for threatened and endangered species.

The job of saving biodiversity is not just up to our governments. Groups such as the Canadian Wildlife Federation and Canadian Nature Federation educate the public and bring issues about biodiversity to our governments' attention. Some groups support conservation efforts financially or through active participation. Science can teach us about biodiverstiy, and maybe even how to preserve it. What we decide to do with this knowledge is up to us.

Off the Wall

Some people believe that the gall bladders of grizzly bears contain special properties. The organs are used in certain folk remedies. There are people who are willing to pay poachers large amounts of money to illegally hunt grizzlies for their gall bladders.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

What can you as an individual do to preserve Earth's biodiversity? One possibility would be to join a group that supports conservation. Research the activities of one such group and write a newspaper article presenting what you find out. You may use a computer to create graphics for your article and to design the layout. To begin your search, go to the web site above, and click on Web Links to find out where to go next.

Find Out ACTIVITY

Protected Areas of the World

Protected areas are preserves, refuges, and national parks set up to protect wildlife and habitat. In Alberta we have national parks, provincial parks, wilderness areas, and forest reserves. Each of these offers different levels of protection for habitat and wildlife. Hunting, logging, mining, and drilling for oil and gas are allowed in some areas but not in others. Protected areas around the world follow the same pattern. Since various uses are permitted in different areas, it can be difficult to assess the effectiveness of protecting these spaces.

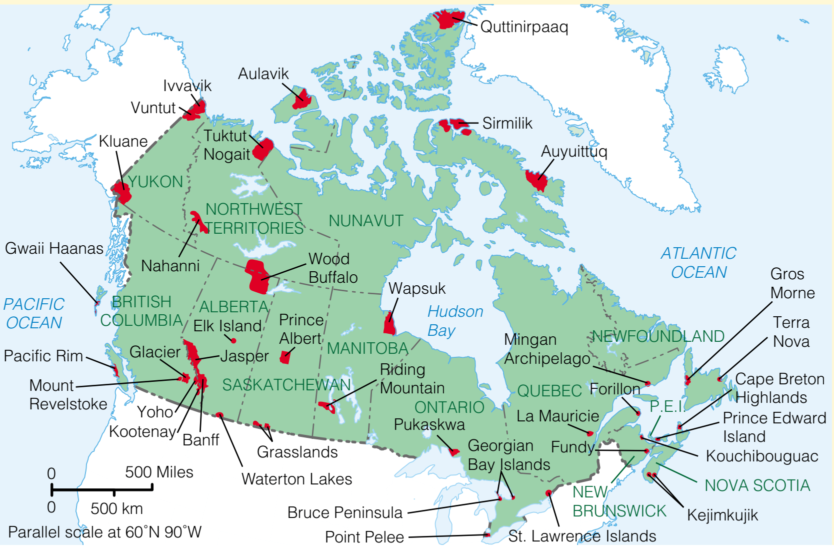
Country	Area of country (km^2)	Area protected (km^2)	% Land protected
North America			
Canada	9 922 385	825 455	8.32
United States	9 372 614	1 042 380	11.12
Mexico	1 972 545	97 287	4.93
South America			
Brazil	8 511 965	321 898	3.78
Costa Rica	50 900	6 386	12.50
Peru	1 285 215	41 762	3.25
Argentina	2 777 815	43 731	1.57
Europe			
France	543 965	56 015	10.30
Germany	356 840	91 957	25.77
United Kingdom	244 880	51 280	20.94
Africa			
Libya	1 759 540	1 730	.10
Sudan	2 505 815	938 250	37.44
Zaire	2 345 410	99 166	4.23
Asia			
China	9 597 000	580 666	6.05
India	3 166 830	143 507	4.53
Mongolia	1 565 000	61 678	3.94

Procedure

Use a bar graph to illustrate the data (percentage of protected area).

What Did You Find Out? ✷ Analyzing and Interpreting

1. What conclusions can you draw from the data? Is there a better way to display the results?
2. The data summarized in the table do not include areas of less than 10 km^2. Does this affect your comparison of the amount of protected area in different countries?
3. What other information would you need to accurately compare the percentage of protected areas between countries? What would you need to know to make this comparison meaningful?
4. Why is it more difficult to create protected areas in some countries than in others?



Canada's National Parks

Computer CONNECT

Enter the data from the table into a spreadsheet. Use the application to draw a computer graph.

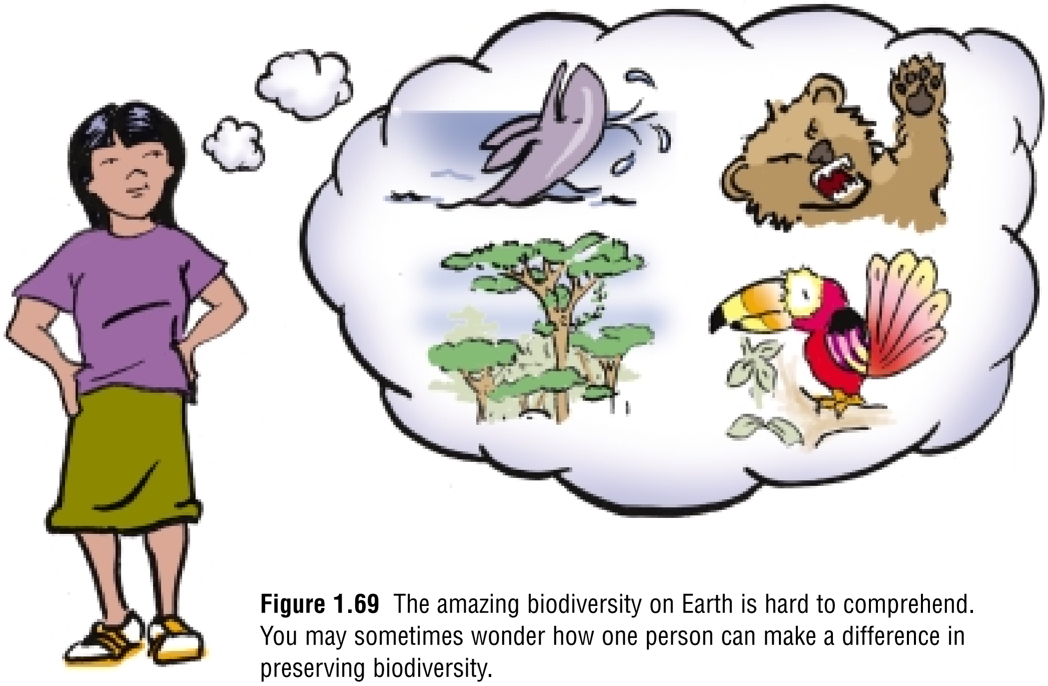


Figure 1.69 The amazing biodiversity on Earth is hard to comprehend. You may sometimes wonder how one person can make a difference in preserving biodiversity.

DidYouKnow?

Some small farms in Mexico and South America grow coffee plants under a canopy of shade trees. This practice provides a habitat for migratory birds, including many that summer in Canada!

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

One approach that is being used to protect endangered species is a sponsorship program. Schools, families, individuals, or companies give contributions to help an individual animal in the wild. To learn about a wolf sponsorship program in Alberta, go to the web site above, and click on Web Links to find out where to go next. Evaluate the strengths and weaknesses of the sponsorship program. Present your ideas in a 5 min talk to a group of students.

DidYouKnow?

Busy highways cut through some of Canada's parklands. To give grizzlies and other wildlife a safe way across the highway, wildlife overpasses have been constructed in some parts of Alberta.

TOPIC 8 Review

1. How can zoos contribute to preserving biodiversity? How do zoos sometimes contribute to decreasing biodiversity?
2. Name five things you could do — without spending money — to help preserve biological diversity.
3. How important is international co-operation in preserving biological diversity?
4. How would you respond to someone who suggested that saving a plant species was not as important as saving an animal species?

Wrap-up TOPICS 6-8

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

domestic animal
artificial selection
selective breeding
natural selection
extirpation
bioindicator species
seed bank
global treaties
protected areas

Reviewing Key Terms

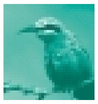
1. How are new breeds of domestic animals developed? (6)
2. Which species are closely monitored to assess human impacts on ecosystems? (7)
3. How can governments ensure wildlife habitats are preserved? (8)
4. What can be done to preserve the genetic diversity of plants? (8)

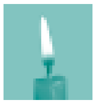
Understanding Key Concepts

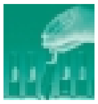
5. Darwin noted that organisms produce more offspring than can survive. How is this important in understanding how natural selection occurs? (6)
6. What accounts for Earth's biodiversity? (6)
7. New discoveries of large animals are extremely rare. Does this mean scientists have a complete catalogue of all of Earth's species? Explain. (7)
8. Why did the process of artificial selection lead Darwin to understand natural selection? Compare and contrast artificial and natural selection. (6)
9. There have been five major declines in Earth's biodiversity in the past. Why should we be concerned that biodiversity is once again declining? (7)
10. Is the "sixth extinction" inevitable? Why or why not? (7, 8)
11. Does natural selection result in variation, or does variation cause natural selection? Explain. (6)

12. Forty or 50 years ago one of the main tourist attractions in Banff was the town dump. Why? What problems did this create? (7)
13. Through natural selection, organisms can adapt to changing environments. Why would changes we make to the environment threaten biodiversity? (6, 7)
14. In the rain forests of Borneo, there is a swimming ant that lives inside the carnivorous pitcher plant. The ant promotes proper digestion for the pitcher plant by removing larger prey insects. How might the pitcher plant be affected should the swimming ant go extinct? How might the loss of the pitcher plant affect the survival of the swimming ant? What do your answers suggest about the consequences of decreasing biodiversity? (7, 8)
15. How can zoos preserve the genetic diversity of certain species? (8)
16. Which areas of the world are the most at risk of losing biodiversity? Why? (7)

UNIT 1







Ask an Expert

John Acorn

Award-winning scientist and television host John Acorn explores Alberta's biodiversity close up. He has written many books and articles about many types of animals and was the host for two nature television programs, *Acorn, the Nature Nut* and the bird-watching show *Twits and Pishers*. These shows allowed him to travel the continent and study the creatures living on it. They also allowed him to communicate with a general audience about his loves — ecology and biodiversity. Acorn's studies of insects led him to discover a new species of beetle, which is being named in his honour.

Q **Is Alberta an ecologically diverse place?**

A We have a lot of variety in the sorts of habitats we have in Alberta, with everything from the alpine zone of the mountains right down to the hot badlands in Dinosaur Provincial Park. My guess — and everyone has a different guess — is that we have around 20 000 species of invertebrate creatures living in Alberta. When you get to a number that big, it doesn't matter if another place has more — it's still diverse!

Q **What areas do you study?**

A I'm interested in looking at what sorts of animals live here (and by animals I primarily mean insects, but I've worked with birds, reptiles, and amphibians, too), what sorts of habitats they require to survive, and where they came from at the end of the last ice age. I'm interested in how their status is changing or has changed over time.

Q **What do you hope to accomplish with your books on species in Alberta?**

A My book on the tiger beetles is a detailed treatment of the 19 species of tiger beetles that we have here. That's a good example of what needs to be done for all our species — to know exactly what their ranges are, something about their life histories and their habitats. It's one thing to say there are X-number of species. It's another to know each species in detail. Then you're really digging in!

Q **What are your latest projects?**

A I'm working on damsel flies right now (the book should be out within a year). I'm also working on ladybugs, larger moths, and dragonflies. I have a long-standing interest in butterflies in Alberta. We have more butterfly counts in Alberta than any other state or province in North America. People from interested kids getting out with their parents to professional entomologists are out surveying our butterflies each year and keeping track of the about 160 species of butterfly.

Q **Can anyone explore biodiversity?**

A Anyone can make important discoveries. When I was in junior high, I found a colony of rare ground beetles that had previously been known in North America only from one specimen in Fort McMurray, and all the rest of these beetles were known from deep in Siberia. For me, that was really exciting because professional entomologists were coming to me for advice on how to find and study this rare beetle. Even as a junior high student, I was able to make a completely new discovery. There is a role for professionally trained biologists with huge grants, but here is also a role for amateurs, from school kids up, to get out there and monitor and explore biodiversity. It just takes time, effort, and a passion for the world around you.

Q **What are some threats to biodiversity in Alberta?**

A The main threats are loss of habitat and introduced species. An introduced ladybug species arrived from the United States and it quickly became the most common species. As a result, some of the species that used to be common are now rare. I've been trying to reconfirm the existence of all the species we knew about before the seven-spot ladybug arrived. We've relocated most of them in smaller numbers, but there are others we haven't found yet.

Also, many of the rare tiger beetle's important habitats in Alberta's prairie sand dunes are being covered up by plant growth. To farmers, dunes are just waste fields, but to many organisms, eroded landscapes such as sand dunes are essential habitats. We're finding that tiger beetles, rare reptiles and amphibians such as the hog-nosed snake, the great plains toad, and the Ord's kangaroo rat require these sand areas as well. There is a lot of biodiversity that's reliant on particular habitats.

Q **Do people associate biodiversity with Alberta?**

A Not always. You hear "biodiversity" and you immediately think of the tropics and the concerns about the Amazon rain forest. It's true that there is more biodiversity in the tropics and that it is in greater danger than it is here. That doesn't mean we should forget about what we have right in front of us. In Alberta, we know enough to know the province's biodiversity is very complex, but we don't know enough to even come close to understanding it.

EXPLORING Further

John Acorn has made a career out of observing and examining creatures he finds more or less in his own back yard. Reread the Ask an Expert feature, and choose one of the organisms he discusses. With a partner, do some research and prepare an illustrated report about the organism. You may wish to gather your class's reports and prepare them as a book for display in your classroom. You may also wish to make your reports available by e-mail to other classes.

An *Issue* to Analyze

A PUBLIC FORUM

To Burn or Not to Burn

Think About It

The provincial government maintains a vast and expensive network of people and machinery to detect and fight forest fires. The government fights fires to prevent damage to public and private property and to protect lives. Commercial forests, sections of the forest that the government leases to companies, are also protected from fires. The trees are used for lumber, paper, or other wood products. Commercial forests provide income for the government and jobs for many people. There is another problem with forest fires — they create air pollution, and the larger the fires, the more pollution they produce.

However, recent evidence suggests that fire prevention programs may have been too successful. You may remember that forest fires play an important role in secondary succession. Research in the Kananaskis Valley suggests that, prior to human intervention, any one area of forest was burnt by naturally occurring fires every 50–75 years. These fires were relatively small and ran out of fuel quickly. The fires opened up space for grasses, bush, and poplar trees. These plants provided food for a variety of animals, such as deer.

Now many national and provincial parks face a problem. Fire suppression over the last 50 years has created forests that no longer support the natural food chains they once did. Also, as trees in these forests die, they become fuel for larger, hotter, and more devastating fires.

How Can Science Help?

In this class activity you will be asked to decide if fires should be allowed to burn in government-controlled forests. What would you need to know in order to thoroughly examine this issue from different angles and come to a wise decision? In your group, write down some questions that you think should be answered. You might want to know if any endangered species live in old growth forests in Canada. What species would benefit from forest fires? As you record your questions, suggest ways that scientists could collect data in order to find out the answers. For instance, scientists may need to monitor animal populations in a specific area. The information that you gather will help you during a public forum with your class to discuss and vote on the forest fire issue.

Plan and Act

① As a class, brainstorm some possible solutions to the forest fire problem. For example, some possible solutions might be:

- Continue to use controlled fires to open up parts of the forest.
- Allow loggers to clear-cut sections of the forest to mimic forest fires.
- Prevent forest fires and allow old growth forest ecosystems to develop.

② Like most social and environmental issues, this issue is complex. Some of the factors that should be considered are:

- *ecological*: concern for the environment
- *economic*: concern for profit and economic security
- *scientific*: interest in knowledge for its own sake and possible applications
- *moral and ethical*: concern for what is "right" and "wrong"
- *technological*: understanding of what is possible/not possible
- *aesthetic*: concern for beauty
- *emotional*: concern for feelings and emotions
- *historical*: interest in learning from the past

Your teacher will assign one of the above factors to your group of two or three students. Your group should find background information on this aspect of the forest fire issue by reading newspaper and magazine articles, watching or listening to local news, or doing research in the library or on the Internet. As a group, consider the possible solutions to the forest fire dilemma. The group should then prepare a 5 min oral presentation on why the factor you have researched is important. You should explain which alternative to the problem your group would choose, taking into account the factor you are discussing. Be sure to present the advantages and disadvantages of this solution.

③ Each group will present its position at the forum. Your teacher will chair the event. After the oral presentations, the class will vote on one solution to deal with the forest fire issue. If the class is split between opposing views, the students who agree with each other should come up with a short description of their views. One student from each side should write the description on the chalkboard.

Analyze

1. How do the possible solutions to the forest fire issue affect the biodiversity of the parks?

2. Do you agree with the class's decision on how to deal with the forest fire issue? Explain why or why not.

3. How did your understanding of science and biological diversity help you to make a decision on the issue at hand?

4. What were some of the challenges of working in a group and as a class? What were some of the advantages of working together?

Extension

5. Write a brief letter stating your views and reasoning on the forest fire issue. Send your letter to a suitable government representative (federal or provincial).

UNIT 1 Review

Unit at a Glance

- All groups of living things show variation. There are variations between species and within species.
- Biological diversity is the number and variety of organisms in an area.
- Organisms show a wide variety of structural and behavioural adaptations.
- Competition within or between species may force groups of organisms to adopt different niches.
- Generalists can survive through the changing seasons of northern climates and spread over large areas. Specialist are well adapted to specific environments and narrow niches.
- Traits that are passed on from one generation to the next are said to be inherited or heritable.
- Clones, or copies of one parent organism, are produced by asexual reproduction. Types of asexual reproduction include binary fission, asexual spores, budding, and, in plants, vegetative growth.
- In sexual reproduction, the genetic information from two parents is inherited. In plants and animals, a sperm fertilizes an egg to form a zygote.
- Some organisms, such as the mould, *Rhizopus*, can reproduce both sexually and asexually.
- Flowers are the reproductive structures of angiosperms. Angiosperms also reproduce vegetatively from the roots or special root, leaf, or stem structures.
- Inherited characteristics that show a limited number of variations, such as tongue-rolling, show discrete variation. Characteristics with a range of possibilities, such as human heights, show continuous variation.
- Some inherited characteristics are dominant to other, recessive traits.
- Not all characteristics are inherited: The environment can influence a person's characteristics. Mutagens alter the genetic information itself.
- DNA is the genetic material and controls the function of cells. Chromosomes, which are found in the nucleus, are made up of coiled strands of DNA. A section of DNA that codes for a specific protein and function is called a gene.
- Sexual reproduction increases variation within a species. Each zygote has a random combination of chromosomes from both parents.
- Transgenic animals and genetically modified crops are important in medicine and food production.
- People have used artificial selection to develop many varieties of domestic animals. Selective breeding is also used to develop new plant varieties.
- Natural selection results in species that are well adapted to specific locales or niches.
- Although Earth has great biological diversity, the current rate of extinction is about one species per day, and possibly many more. As a result, Earth's biological diversity is declining.
- Zoos and seed banks are two ways in which people try to maintain biological diversity. Protected areas and global treaties have also been set up to protect endangered plants and animals.

Understanding Key Concepts

1. How do we recognize biological diversity? What are some different forms of biological diversity?
2. Describe the function of DNA.
3. Describe a situation in which an area with a high diversity index is healthier than an area with a low diversity index.
4. (a) Describe how an organism reproduces by budding.

   (b) State one advantage of this type of reproduction.

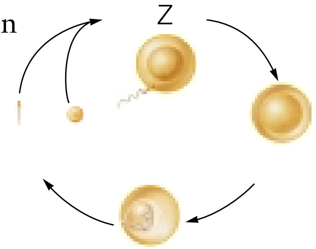
5. Give an example of a generalist that lives in Canada. Explain why this species is able to have a broad niche.

6. Give an example of a behavioural adaptation and an example of a structural adaptation. How is each adaptation suited for a specific niche?

7. (a) Explain and give examples of how plants can reproduce from roots, stems, and leaves.
   (b) Why are plants produced by these methods considered identical to the parent plant?

8. Give an example of a dominant trait that is uncommon in certain human populations.

9. Redraw this figure in your notebook. Label the cells and structures in the diagram. What happens after cell z is formed?



10. What must each mushroom spore contain in order for it to produce a new mushroom?

11. Describe three human traits that show continuous variation.

12. (a) What are some examples of observations that led Darwin to propose the theory of natural selection?
    (b) What are the four statements that describe natural selection?

13. Why do some environments, such as the tropics, support such great biological diversity?

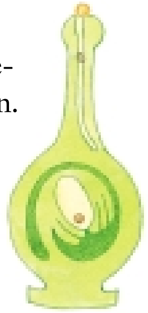
14. What are the dangers of having a narrow niche?

15. Describe five ways in which individuals and groups of people can help preserve biological diversity.

16. Give one reason why the conversion of tropical forests into farmland has generally been unsuccessful.

17. List four human impacts on biological diversity. How have people affected Earth's biological diversity?

18. (a) Redraw this diagram in your notebook and label the structures shown.
    (b) Explain how, when, and where the pollen tube forms.
    (c) What is the purpose of the pollen tube?



Developing Key Skills

19. "Sexual reproduction is more effective than asexual reproduction, and it is only a matter of time before all living organisms reproduce that way exclusively." In teams, prepare arguments either for or against this statement. Support each argument with a quote or an example. Each team will present its argument in a class debate.

20. Suggest an experiment to measure the biological diversity in a pond. Why would this information be important to know?

21. Make a Venn diagram (two overlapping circles) showing the relationship between selective breeding and genetic engineering. In the overlapping area of the circles, write the things that the two have in common. In the areas that do not overlap, write the things that are different.

22. How could you measure the diversity index of flowers in a meadow? What precautions would you take to preserve the flowers you are studying? Would it be important to include a study of the insects in the meadow as well? Why or why not?

23. Fern leaves grow from tightly coiled, tender spirals called *fiddleheads*. Although fiddleheads have been collected as a vegetable delicacy for ages, they are mildly toxic. How would this feature help a fern survive? How could you test your hypothesis?

Problem Solving/Applying

24. Genetic fingerprints can be used to find out if two or more animals in a population are closely related. Explain why biologists might want to compare the genetic fingerprints between captive cheetahs in a zoo. How could biologists use the information to preserve the cheetah as a species?

25. There are fewer than 400 whooping cranes in the world. These large birds breed in the wetlands of northern Alberta and winter in the southern United States. Propose an action to help preserve this endangered species.

26. Blueberry farmers rely on bees to pollinate blueberry flowers. Wild bees are also important in natural ecosystems. Describe one possible role of wild bees and how human actions may affect wild bee populations.

27. Propose a theory that explains why bacteria, protists, fungi, and some invertebrates tend to reproduce asexually, while most vertebrates never reproduce this way. How could you test your theory?

Critical Thinking

28. If candy colour were a genetic trait, would Smarties® show continuous or discrete variation?

29. (a) Suggest some reasons why mating does not ensure successful reproduction.
    (b) What is the function of fertilization? Suggest some reasons why fertilization alone does not ensure successful reproduction.

30. Biologists would like to preserve corridors connecting wildlife, such as grizzly bears, in Canada and the United States. Why are these corridors important for the long-term survival of these animals?

31. Some invertebrates, such as crabs, have the ability to regrow body parts that have been lost through injury. What cell part do you think scientists study to learn more about the process of regeneration in these animals?

32. How does the story of antibiotic resistance illustrate the importance of variation?

33. Herbicide-resistant plants are usually selected to resist specific herbicides. Why would it be an advantage for a company to produce both the genetically modified seed and the herbicide?

34. A mutation that results in faster growth of a plant could be advantageous. Explain why.

35. One of the stated objectives of zoos and wildlife preserves is the protection of endangered species. However, many people believe that keeping animals in captivity is wrong. List arguments for:
    (a) allowing animals to become extinct in their natural habitats and
    (b) saving them in the basically unnatural habitat of zoos and preserves.

36. How does the environment affect the artificial selection of farm animals such as goats? Did the environment play a role in the natural selection of mountain goats?

37. The coelacanth is an ancient marine fish. For many years, people mistakenly thought the coelacanth was extinct. The unexplored depths of the oceans probably contain many other species of plants, animals, and bacteria that have never been discovered.
    (a) Light does not penetrate to the greatest depths of the sea. Describe some possible adaptations that would be useful for life at the bottom of the ocean.

(b) Give some reasons why it would be important to learn about biological diversity in the oceans.

(c) Why do you think some people are encouraged by the story of the coelacanth?

38. The populations of some shark species are declining. Sharks are killed not only because they are seen as dangerous predators. Sharks are also hunted for food and for their cartilage, which is used in certain medicines. However, sharks have an important role as scavengers in the oceans. Speculate what might happen if large sharks became extinct. Write down the advantages and disadvantages of preserving sharks.

39. Mosquito eggs hatch only when there is enough moisture. Explain how this adaptation affects mosquito populations from year to year.

40. The carnivorous sundew has underdeveloped roots and is covered by sticky secretions. Charles Darwin once wrote: "I care more about the origin of the sundew than the origin of all the species in the world." What are some adaptations of the sundew that may have attracted Darwin's interest? What makes these adaptations different from many other plants?

sundew

41. Purple loosestrife has caused extensive damage in Alberta since its introduction. However, this plant has some natural enemies. Do you think it would be a good idea to introduce new species that are predators or pests of purple loosestrife? Why or why not?

42. Atlantic salmon are sometimes raised off the coast of British Columbia. Large numbers of these fish have escaped, and a few have been found in rivers in British Columbia, which are the natural habitat of Pacific salmon. Why are some people concerned about the escape of farmed Atlantic salmon into Pacific waters?

43. Many monarch butterflies summer in Canada and winter in Mexico. The loss of their wintering grounds is a major threat. How else do you think people might impact populations of monarch butterflies?

44. Why are there so many insect species relative to other animal species?

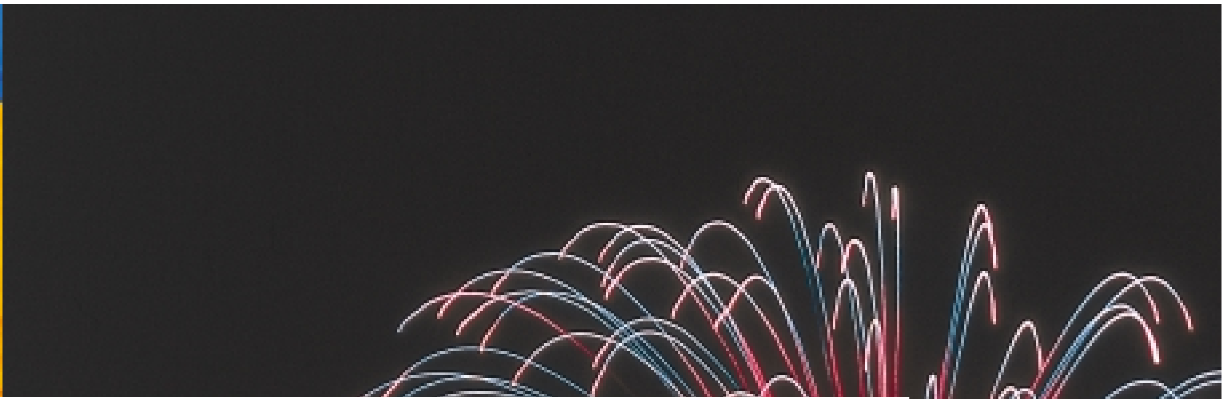
45. Scientists are investigating the possibility of growing animals from unfertilized eggs. What term describes the offspring in relation to the mother in this situation? Scientists may be able to use this technique with human eggs in the future. What would be the pros and cons of using this technique with human eggs?

Pause& Reflect

1. Identify a specific issue raised by this unit. Explain why it is important to you. What knowledge would be important to have in order to resolve this issue?
2. Now that you have completed this unit, review your answers to the Focussing Questions on page 4. Would you now answer differently? Based on what you have learned from Unit 1, write new answers to these questions in your Science Log.

UNIT 2

Matter and Chemical Change



Ah, pizza! How appetizing! Imagine the taste of melted cheese, fresh veggies, and tangy tomato sauce. Pizza is a colourful, fragrant, mouth-watering assortment of ... chemicals?

Yes, when you bite into pizza you are tasting a mouthful of chemicals. When you watch a spectacular fireworks display, you are observing chemical properties. And when you fry an egg, bake a cake, or observe autumn leaves, you are seeing chemicals at work. What other chemical changes can you name?

The matter that surrounds you constantly interacts and changes both chemically and physically. How is matter sorted out and classified? Which substance is which? Can the changes be understood or predicted? Which chemicals are safe to handle? What is the difference between the chemicals in fireworks and the chemicals in the food we eat?

Investigate the fascinating world of chemical change in Unit 2. Observe and compare chemical substances and the ways they interact.

What mysteries about chemicals would you like to solve?

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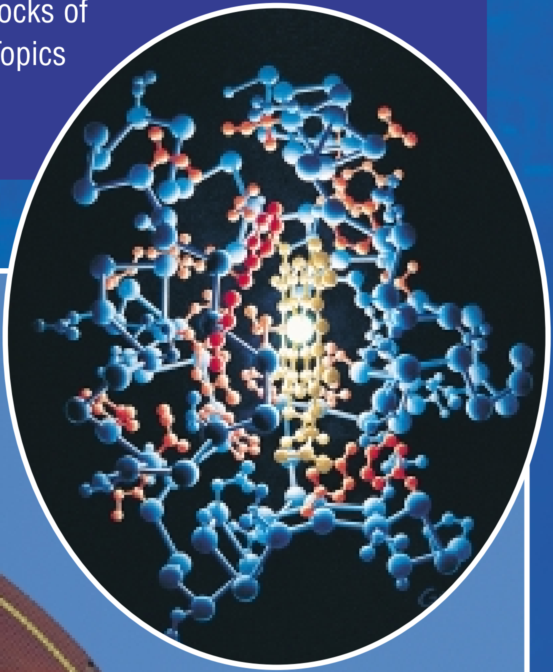
UNIT 2

Preview

Focussing Questions

- What are the properties of materials and what happens to the properties during chemical change?
- How do we know that chemical change occurs?
- What ideas, theories, and models help explain chemical change?

Imagine breaking a piece of matter into smaller and smaller pieces — so small that you would need a powerful microscope to see them. What would be the smallest piece? How could you decide whether it was a pure substance or a mixture? Dig into the building blocks of matter in Topics 1–3.

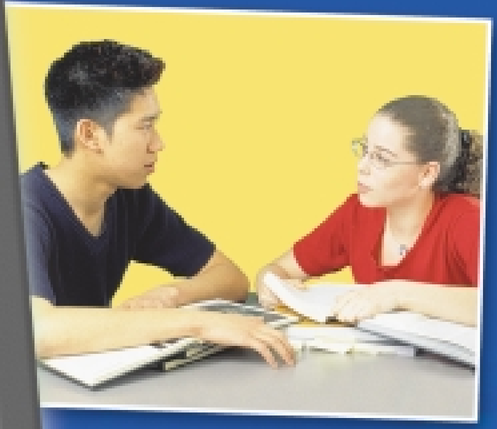


Neon signs create a dazzling display thanks to the properties of elements. How are elements classified? What properties do elements have? Prepare to be dazzled as you find the answers in Topics 4–6.

Do chemical reactions happen only in laboratories? Or can you see them all around you every day? How can chemicals react to produce new substances? The answers are waiting for you in Topics 7–8.

Looking Ahead

Look ahead to the Unit Investigation: Tough as Nails on pages 168–169. In this investigation you will choose a question to investigate about a chemical process and design the steps of an experiment to answer your question. While you work through this unit, notice safety information that will be useful in planning your investigation. Start thinking now about your contributions to the group process. How can you help make decision making smooth and easy? How can you communicate your ideas while also encouraging others to participate?



TOPIC 1

Exploring Matter

Did You Know?

When this textbook was published, Canadian scientists had won the Nobel Prize in science ten times. Many of the Nobel laureates were chemists. Visit the web site **www.science.ca**. Why were the scientists awarded the prize? What were their lives like when they were your age? Have any other Canadian scientists been awarded the Nobel Prize since this list was created?

Bertram Brockhouse (1994 Physics)
Michael Smith (1993 Chemistry)
Rudolph Marcus (1992 Chemistry)
Richard E. Taylor (1990 Physics)
Sidney Altman (1989 Chemistry)
John Polanyi (1986 Chemistry)
Henry Taube (1983 Chemistry)
David Hubel (1981 Medicine)
Gerhard Herzberg (1971 Chemistry)
Frederick Banting (1923 Medicine)

You are surrounded by matter. The air you breathe, the clothes you wear, and the food you eat are all examples of matter. What is known about matter? How were the discoveries made? Many answers have come from **chemistry**, the study of the properties of matter and the changes matter undergoes.

The chemistry laboratories shown in movies and television programs often look like the laboratory in the large photograph above. But much of what we know about matter today was discovered in laboratories that were far less advanced, using simple equipment, as shown in the sketch above. Some early chemists had private sources of funding, so they could hire metalworkers and glass blowers to make specialized equipment. Many early chemists were poor, however, and used whatever materials were at hand to make their own equipment. Even with this homemade equipment, they were able to make important discoveries to further the understanding of matter.

Safety First

Although early scientists made many important discoveries, their laboratories were not as safe as the one you will work in this year. Some scientists routinely tasted and smelled chemicals. Safety goggles were rarely worn. Explosions were common and many early scientists met an unfortunate death.

Chemicals must be handled with care. Some materials are **caustic** and will burn, corrode, or destroy organic tissue.

A good laboratory is a safe laboratory. The investigations and activities you perform in your class are carefully monitored by your teacher. The procedures, equipment, and chemicals must all meet strict safety guidelines. You can help to make your laboratory a safer place. Which safety symbols and procedures do you need to know? Find out in the next two activities.

Did You Know?

Modern chemists must always be alert for safety concerns. Some chemicals can be very dangerous either alone, or in combination with other chemicals. In 1995 a chemist was studying how heavy metal poisons cause damage to human cells. She wore latex gloves as she carefully poured a mercury compound into a tube. A tiny amount of the toxic compound accidentally spilled onto her glove. Within 15 s the compound was absorbed through the glove into her skin. Less than a year later, the chemist died from mercury poisoning.

Find Out ACTIVITY

Put Safety First

Are you familiar with the Workplace Hazardous Materials Information System (WHMIS) Safety Symbols? Do you recognize the safety symbols that appear within this textbook?

Procedure

1. Turn to Skill Focus 1, Safety Symbols. Read about the WHMIS symbols and the safety symbols used in this textbook.
2. Copy the following descriptions of products into your science notebook.
3. Sketch the corresponding WHMIS safety symbol next to each description. Record an example of each.
4. **Communication and Teamwork** Find a partner and quiz each other about the safety symbols used in investigations in this textbook. Turn to several investigations and ask each other what the symbols mean.

Description	Symbol	Example
Compressed gas		
Poisonous and infectious material causing immediate and serious toxic effects		
Poisonous and infectious material causing other toxic effects		
Oxidizing material		
Flammable and combustible material		
Corrosive material		
Biohazardous infectious material		
Dangerously reactive material		

What Did You Find Out?

1. Which WHMIS symbols do you think you might see on materials in this unit?
2. List the safety symbols displayed in investigations and activities in this unit.
3. Why is it important for you to recognize safety symbols?

Find Out ACTIVITY

Fasten Your Safety Seat Belt

As you read these words, hundreds of scientists are working in laboratories across Canada learning more about the chemicals we use every day. The most important part of every one of those laboratories is the safety equipment. Where is the safety equipment in your laboratory? Do you know how to use it? Suppose you cut yourself during an investigation. Would you know where to find the first-aid kit?

Procedure

1. Review the sample list of safety equipment.
2. Draw a large, aerial (bird's-eye) view of your classroom.
3. Clearly label the name and location of each piece of safety equipment in your classroom.
4. **Communication and Teamwork** Work with a partner or in a small group. Take turns quizzing each other about the location and use of each piece of safety equipment.

Sample List of Safety Equipment

fire extinguisher
fire blanket
safety goggles
aprons
broken glass container
first-aid kit
WHMIS chart
fire exit
acid neutralizer
base neutralizer
eyewash station
telephone
dustpan and brush
safety charts
safety shield

What Did You Find Out?

1. Which piece of equipment do you feel is the most important? Why?
2. Why must all broken glass be put in a special container?
3. What other special storage containers are in your classroom?

Extend Your Skills

4. What type of fire extinguisher is in your classroom? How is it used?
5. Make a list of the safety equipment you have in your home. Which equipment do you know how to use?
6. How are toxic wastes, such as paint and used batteries, disposed of in your community?

Computer CONNECT

Use the keywords "WHMIS symbols" to start an Internet search. Find a site displaying the WHMIS symbols. Download the symbols and use them to create a safety poster, website, or brochure. Be sure to follow your school's guidelines for downloading information.

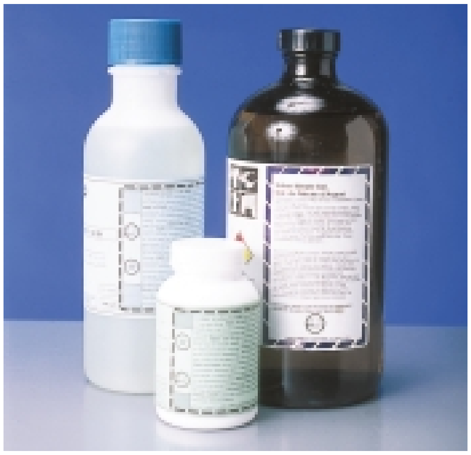


Figure 2.1 Which WHMIS symbols can you find on these containers?

Classifying Matter

Chemistry includes facts and observations about matter, laws that summarize patterns of behaviour in matter, and theories that explain the patterns of behaviour. For example, you may recall the particle model of matter from your earlier studies. This model is summarized below.

The Particle Model of Matter

- All matter is made up of extremely tiny particles.
- Each pure substance has its own kind of particle, different from the particles of other pure substances.
- Particles attract each other.
- Particles are always moving.
- Particles at a higher temperature move faster on average than particles at a lower temperature.

The particle model of matter is one example of a scientific model. Scientific models help us to visualize processes that cannot be seen directly. For example, in the particle model of matter, the individual particles would be far too small and move too quickly to be observed directly. You can use the first two points of the particle model to imagine how particles might make up substances. The other three points of the particle model can explain properties such as density and how matter behaves when temperature changes occur.

You have already learned that matter can be classified according to its state as a gas, a liquid, or a solid (see Figure 2.2).

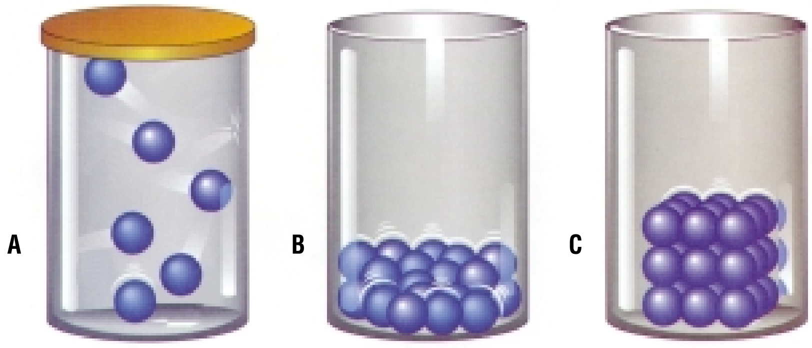


Figure 2.2 Attractive forces between particles are weakest in gases (A), stronger in liquids (B), and strongest in solids (C). Note that gas particles are much farther apart than shown here.

Matter can be further classified according to its composition as a mixture or a pure substance (see Figure 2.3 on the next page). Each pure substance contains its own unique kind of particle. Mixtures contain at least two kinds of particles.

Skill FOCUS

For more information about scientific models, turn to Skill Focus 12.

Pause& Reflect

Based on the particle model, draw simple sketches in your Science Log to illustrate the following:

- evaporation of water from a puddle
- solidification of hot liquid lava on a mountainside
- a cold lake
- a hot bath

Mixtures can be classified by their properties. If the particles are uniformly scattered, the mixture is **homogeneous**. If the particles are not uniformly scattered, the mixture is **heterogeneous**.

The classification chart in Figure 2.3 is based on the particle model. However, there is more than one way to classify matter. In this unit, you will see other ways that chemists use to classify thousands of pure substances and millions of mixtures.

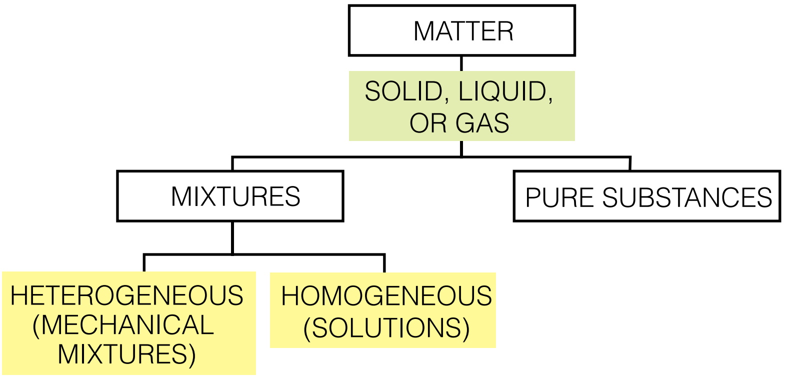


Figure 2.3 A classification system based on the particle model

Find Out ACTIVITY

A Classification Puzzle

Brush up on your classification skills by classifying several samples of matter.

Materials

8 vials containing unidentified mixtures or pure substances (provided by your teacher)

Appendix C: Properties of Common Substances

Procedure ✷ Performing and Recording

1. Copy the table below to record your observations and inferences. Give your table a title.

Vial number	Observations	Probable classification	Reason for classification	Probable identity

2. Your teacher will give you eight vials that contain unidentified samples. Three vials contain heterogeneous mixtures, three contain pure substances, and two contain homogeneous solutions. Inspect the contents of each vial visually. *Do not open the vials.*
3. Examine the following list: calcium carbonate (chalk, crushed), carbon (graphite), copper (II) sulfate, glycerol (glycerine), iron filings, rock salt, sugar, vegetable oil, water, and zinc. The vials contain only materials in this list, but some vials may contain two of the materials.
4. Using your observations, classify each sample as homogeneous or heterogeneous. Determine a probable identity for each substance in each heterogeneous mixture using your observations and Appendix C. Record your ideas in your chart.
5. You should now have five vials that are unidentified. These vials contain homogeneous materials. Using Appendix C and your observations, find the three pure substances. Determine a probable identity for each pure substance. Record your ideas in your chart.
6. The remaining two vials contain solutions. Use your observations and Appendix C to determine a probable identity for each substance. Record your ideas in your chart.

What Did You Find Out? ✷ Analyzing and Interpreting

1. How are solutions different from mechanical mixtures? What similarities do they have?
2. Which vials contained materials that were difficult to classify? Why were they difficult?

Extension

3. Examine bottles and jars in your refrigerator at home. Classify the contents as mixtures or pure substances. Which are more common?

Mixtures of Matter

Most matter is found in the form of homogeneous or heterogeneous mixtures. Homogeneous mixtures (solutions) are usually clear if they are liquids and cannot be filtered to separate the particles. The scattering of light cannot be seen when you shine a flashlight in a solution. Heterogeneous mixtures (mechanical mixtures) can be further classified based on the size of particles (see Figure 2.4).

In ordinary mechanical mixtures, the different parts are big enough to see, and they stay mixed. For example, granite is an ordinary mechanical mixture because you can see the particles of quartz, feldspar, and mica.

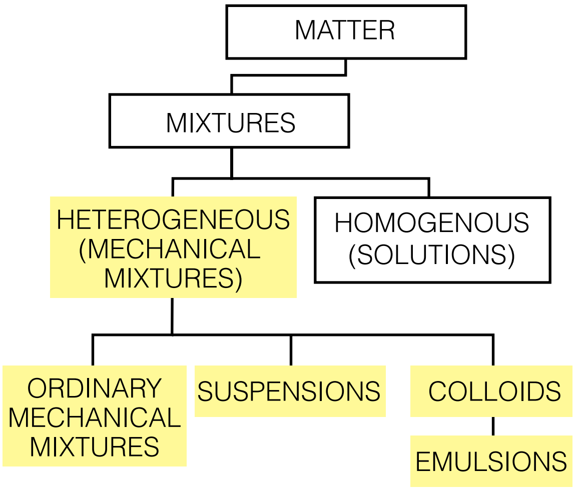


Figure 2.4 A classification of heterogeneous mixtures

A suspension is a heterogeneous mixture made of large particles that are uniformly mixed but will settle if left undisturbed. Examples of suspensions include flour, charcoal, or powdered chalk mixed in water. Suspensions can be separated by filtering and will scatter light.

Colloids are heterogeneous mixtures composed of fine particles evenly distributed throughout a second substance. Examples of colloids include hair gel and clouds. Whether a mixture forms a solution, colloid, or suspension depends on the size of the particles, solubility, and mixing ability (miscibility).

Emulsions are types of colloids in which liquids are dispersed in liquids. Examples of emulsions include mayonnaise, milk, jelly, and salad dressing. Many emulsions quickly separate to form layers of the original liquids. For example, shaking oil and vinegar salad dressing creates an emulsion, but the dressing soon separates into layers of oil and vinegar. The addition of an emulsifying agent may keep a liquid dispersed in another liquid. If a suitable emulsifying agent is added to oil and vinegar salad dressing, the oil droplets cannot clump together to form a separate layer. You will investigate emulsions in the next Find Out Activity.

Figures 2.5A and 2.5B One way to tell the difference between a solution and a colloid is to shine a light through them. A solution will not allow the light to scatter. A colloid will scatter the light because the particles are larger than those in a solution. This light-scattering property of colloids is called the Tyndall effect. Is the fog shown in the picture a colloid or a solution?

STRETCH Your Mind

Have you seen what happens when drops of detergent are added to a mixture of homogenized milk and food colouring? Try it. The results are quite amazing. Milk is a type of hydrophilic (“water loving”) colloid. Fat stays suspended in the milk because of the emulsifying agent casein. The water-loving casein attaches itself to the water and the fat therefore stays suspended. One part of a detergent particle is hydrophilic and another part is hydrophobic (“water hating”). Use this information to explain what happens when detergent is added to the milk and food colouring mixture. Draw a diagram. Can you explain how detergents are able to remove an oil molecule from the water?

Find Out **ACTIVITY**

Keep It Together

Without emulsifying agents, many products would have to be shaken before being used. Try this activity to see which ingredients work as emulsifying agents. Be sure to measure all substances carefully.

Safety Precaution

Materials

medicine dropper
test tubes
test tube rack
masking tape
rubber stoppers
metric measuring spoon
vinegar
cooking oil
eggs
baking soda
dishwasher liquid
cornstarch

Procedure ✹ Performing and Recording

1. Label seven test tubes from 1–7 and place them in a test tube rack or large beaker.
2. Measure 5 mL of vinegar and 5 mL of cooking oil into each test tube.
3. Test tube 1 will be the control for the investigation. After you have added substances to the other test tubes, they can be compared to test tube 1.
4. Add ten drops of egg yolk to test tube 2. Stopper the test tube and shake for 60 s. Does the mixture separate or remain a suspension? Record your observations.
5. Repeat step 4 for test tubes 3–7, but instead of egg yolk, use egg white in #3, beaten eggs in #4, 1 mL baking soda in #5, dishwashing liquid in #6, and 1 mL cornstarch in #7. Record all observations carefully.

What Did You Find Out? ✹ Analyzing and Interpreting

1. Which substances acted as emulsifying agents?
2. Did you make any permanent suspensions?
3. Which substances did not make emulsions? Why do you think this happened?

Extensions

4. Look on the labels of liquid food products at home. Which contain emulsifying agents? What would happen if the emulsifying agents were not present?
5. Look on the labels of personal care products at home. Which contain emulsifying agents? What would happen if the emulsifying agents were not present?

TOPIC 1 Review

1. Draw the WHMIS symbols for three hazardous materials. Explain the meaning of each.
2. List eight pieces of safety equipment you feel are necessary for a safe school science laboratory.
3. Use the particle model to explain the differences among a pure substance, a solution, and a mechanical mixture. Give one example of each.
4. Classify each of the following as a pure substance, a mechanical mixture, or a solution. How did you decide for each?
   (a) soil
   (b) perfume
   (c) baking powder
   (d) glass cleaner
5. **Thinking Critically** When most people think of solutions, they think of a solid dissolved in a liquid. Solutions that involve other states of matter are possible. Give an example of each solution below.
   (a) gas dissolved in a gas
   (b) gas dissolved in a liquid
   (c) liquid dissolved in a liquid

TOPIC 2 Changes in Matter

Every kind of matter has properties that can be used to identify the matter. Properties are the characteristic ways in which a substance behaves. Examples of properties include the strength of the ice on a skating rink, the smooth surface of writing paper, and the taste of chlorinated water. However, properties can change. Ice can melt and lose its ability to support skaters. Paper can burn and become useless for writing. Chlorinated water, left overnight, can lose its strong taste.

Chemists classify changes in matter into two categories: physical changes and chemical changes. During a **physical change** a substance changes in form but not in chemical composition. No new substances are formed. Ice melting is an example of a physical change. The new properties are temporary because a change of state can be reversed. The liquid water can easily be converted into solid ice again.

The taste of the chlorinated water is also the result of a physical change. The taste is caused by chlorine dissolved in the water. If the solution stands overnight, it separates and most of the dissolved chlorine escapes. The chlorine particles still exist, with all of their properties unchanged, but they are now dissolved in the surrounding air instead of being dissolved in the water.

A **chemical change** causes one or more new substances to be formed. A chemical change may be difficult or impossible to reverse (see Figure 2.8). Burning paper is an example of a chemical change. The smoke that escapes and the black solid that is left behind cannot be recombined again to form paper — the change cannot be reversed. You will observe physical and chemical changes in the next investigation.

Figure 2.6 Are brilliant colours in leaves the result of physical or chemical change?

Figure 2.7 Hockey players can move quickly over the ice because the ice melts under the pressure of the skate blades and reduces friction. The melted ice resolidifies quickly on the sheet of ice.

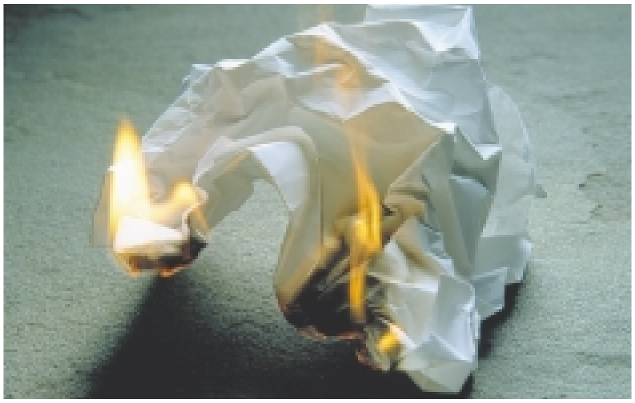


Figure 2.8 How is the change shown in this picture different from the change shown in Figure 2.7? Which change is physical, and which is chemical? How do you know?

INQUIRY

INVESTIGATION 2-A

SKILLCHECK

Initiating and Planning

✸ Performing and Recording

✸ Analyzing and Interpreting

Communication and Teamwork

Physical and Chemical Changes in Ancient Alberta

Did you know that Alberta was covered by ocean water in its ancient past? Many physical and chemical changes occurred in and around these bodies of water. Alberta's present landscape and mineral resources are partly a result of the changes. For example, much of the rock exposed in the mountains contains carbonates, such as dolomite and limestone. In this investigation you will duplicate the chemical changes that created carbonates in the rocks. You will test the results using hydrochloric acid, a standard test for carbonates in rocks.

Question

What physical and chemical changes occur when two solutions are mixed together?

Safety Precautions

- Avoid contact of the acid with your skin. If you accidentally spill acid on your skin, wash it off immediately with lots of cool water and inform your teacher.

Apparatus

2 test tubes
2 rubber stoppers for test tube
10 mL graduated cylinder
funnel
beaker
medicine dropper
balance
retort stand
ring clamp or burette clamp
tongs
watch glass
hot plate
evaporating dish
test tube rack
scoopula

Materials

water
sodium carbonate
calcium chloride
filter paper
dilute hydrochloric acid (1 mol/L)

Procedure

1. Make an observation chart like the example shown below.
2. **Label** the test tubes A and B.
3. Put on your safety goggles and apron. Leave them on for the entire investigation.

	Observations
Part 1	
Part 2	
Part 3	

Part 1

4. **Measure** 10 mL of water into test tubes A and B.
5. Add 1 g of sodium carbonate to the water in test tube A. Stopper the test tube and shake it until all the chemical has dissolved. Place the test tube in a test tube rack.
6. Add 1 g of calcium chloride to the water in test tube B. Stopper and shake the test tube until all of the chemical has dissolved.
7. Pour the contents of test tube A into test tube B. Stopper it and shake it a few times. If you have a jelly-like substance, add a small amount of water to the test tube.
8. **Observe** the results. **Record** your observations in the chart. Save your mixture.

Part 2

Procedure

1. Fold the filter paper. Place the folded filter paper in the funnel and dampen it with water to hold it in place.
2. Hold the funnel over the beaker or attach it to the retort stand with a clamp.

③ Pour the mixture from test tube B into the funnel. Allow all of the mixture to filter through the filter paper into the beaker. Save both the filtrate (liquid that passed through the filter) and the residue (material trapped in the filter paper).

④ Place the filter paper and residue on a watch glass.

⑤ Use the dropper to add five drops of dilute hydrochloric acid (1 mol/L) to the residue on the filter paper. **Observe** the results.

⑥ **Record** your observations.

Part 3

Procedure

① Be sure the hot plate is in a safe place. Plug it in.

② Pour some of the filtrate (liquid in the beaker) into the evaporating dish.

③ Put the evaporating dish on the hot plate.

④ Heat the liquid until almost all of it has evaporated. **Observe** carefully. As the liquid evaporates, it may "spit" small particles out of the dish.

⑤ Use tongs to remove the evaporating dish from the hot plate just before all of the liquid has evaporated. Unplug the hot plate.

⑥ **Observe** the results. **Record** your observations.

⑦ Clean all equipment and return it to the proper location. Dispose of chemicals as directed by the teacher.

Analyze

1. What happened when you poured the two solutions together in Part 1?
2. Describe what happened when the hydrochloric acid was added to the residue in Part 2. What did this tell you about the residue?
3. Describe the residue left in the evaporating dish. What substance did it appear to be?

Conclude and Apply

4. Describe the chemical change(s) in this investigation.
5. Describe the physical change(s) in this investigation.
6. Sometimes when solutions are mixed together an insoluble substance is formed called a precipitate. Which of the steps created a precipitate?

Extend Your Knowledge

7. Did this simulation illustrate how Alberta's carbonate rocks were formed? Why or why not?
8. What connection might there be between the calcium carbonate rocks in Alberta and the large deposits of salt in Saskatchewan?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To find out more about ancient chemical and physical changes, go to the web site above, and click on Web Links to find out where to go next. Use the information you find to create an events chain.

Find Out **ACTIVITY**

What's in the Bag?

What kinds of changes can matter undergo?

Safety Precautions

- Open the bag carefully in steps 2 and 4. Point the opening away from anyone's face. If any solution comes in contact with your skin, wash it off immediately with lots of cool water. Inform your teacher of the accident.

Materials

20 mL warm water
5 mL phenol red solution
resealable plastic bag
5 mL calcium chloride
5 mL baking soda

Procedure ✸ Performing and Recording

1. Pour 20 mL warm water and 5 mL phenol red solution into the bag. Seal the bag. Gently shake the bag. Feel the outside of the bag.
2. Carefully open the bag. Add 5 mL calcium chloride. Seal the bag and gently shake it. Feel the outside of the bag.
3. Record your observations.
4. Carefully open the bag. Add 5 mL baking soda. Seal the bag and gently shake it. Feel the outside of the bag.
5. Record your observations.

What Did You Find Out? ✸ Analyzing and Interpreting

1. List the starting materials. Describe their properties.
2. What happened to the starting materials? Describe the changes in properties that you observed.
3. Were the changes physical or chemical? How can you tell?

Can You Ever Be Sure About Changes?

It can be difficult to decide if a change is physical or chemical. Here is a rule that can help you: If you make two or more of the following observations, then a chemical change has *probably* taken place.

- Heat is produced or absorbed.
- The starting material is used up.
- There is a change in colour.
- A material with new properties forms.
- Gas bubbles form in a liquid.
- A precipitate forms in a liquid.
- The change is difficult to reverse.

Why does the rule say *probably*? Changes in properties can be misleading. You cannot be sure that a chemical change has occurred unless you are certain that a new substance has been formed. You cannot be certain that a new substance has been formed unless you do careful tests both before and after the change.

Figure 2.9 Has this watermelon just undergone a physical or a chemical change?

Properties: Chemical or Physical?

If you want to understand the changes that matter undergoes, you need to know the properties of the matter. For example, Canadian aerospace engineers need to know everything about the materials used in the construction of Canadarm and how the materials might change. Will the materials melt in extreme heat, become brittle in the cold, or react with other materials? Chemists classify properties to gain a better understanding of matter. Table 2.1 shows some properties of two pure substances: helium and hydrogen.

Table 2.1 Properties of Helium and Hydrogen

Properties	Helium	Hydrogen
colour	colourless	colourless
density	low (0.18 g/L)	very low (0.09 g/L)
combustibility	does not burn	burns explosively

Any property that can be observed or measured without forming a new substance is a physical property. Density is the amount of matter that occupies a certain space, or in other words, the mass per unit volume of a substance. Density can be measured without forming a new substance, so density is a physical property.

Suppose you had one balloon filled with hydrogen, and another balloon filled with helium (see Figure 2.10). How could you tell which was which? If you could see inside the balloons, both gases would be colourless, so you could not distinguish the gases by colour. Both balloons would float in air, since both gases have a low density.

There would be a difference, however, if each gas were exposed to a flame. Helium would not burn at all. Hydrogen would burn explosively. The ability of a substance to burn in oxygen is called combustibility. Combustibility is not a physical property because combustion creates new substances.

Any property that describes how a substance reacts with another substance when forming a new substance is a chemical property. Combustibility is therefore a chemical property. Hydrogen burns in oxygen, so it has the property of combustibility. Helium does not burn in oxygen, so it does not have the property of combustibility. Knowing that something is not combustible may be just as important as knowing that it is.

Cool Tools

To survive the fierce heat of re-entering Earth's atmosphere, the space shuttle uses a system of heat-resistant tiles. These tiles can be removed from an oven at 1200°C and put straight into cold water without cracking. The tiles are made from silica and ceramic bonding materials.

Figure 2.10 How could you tell if these balloons contained hydrogen or helium?

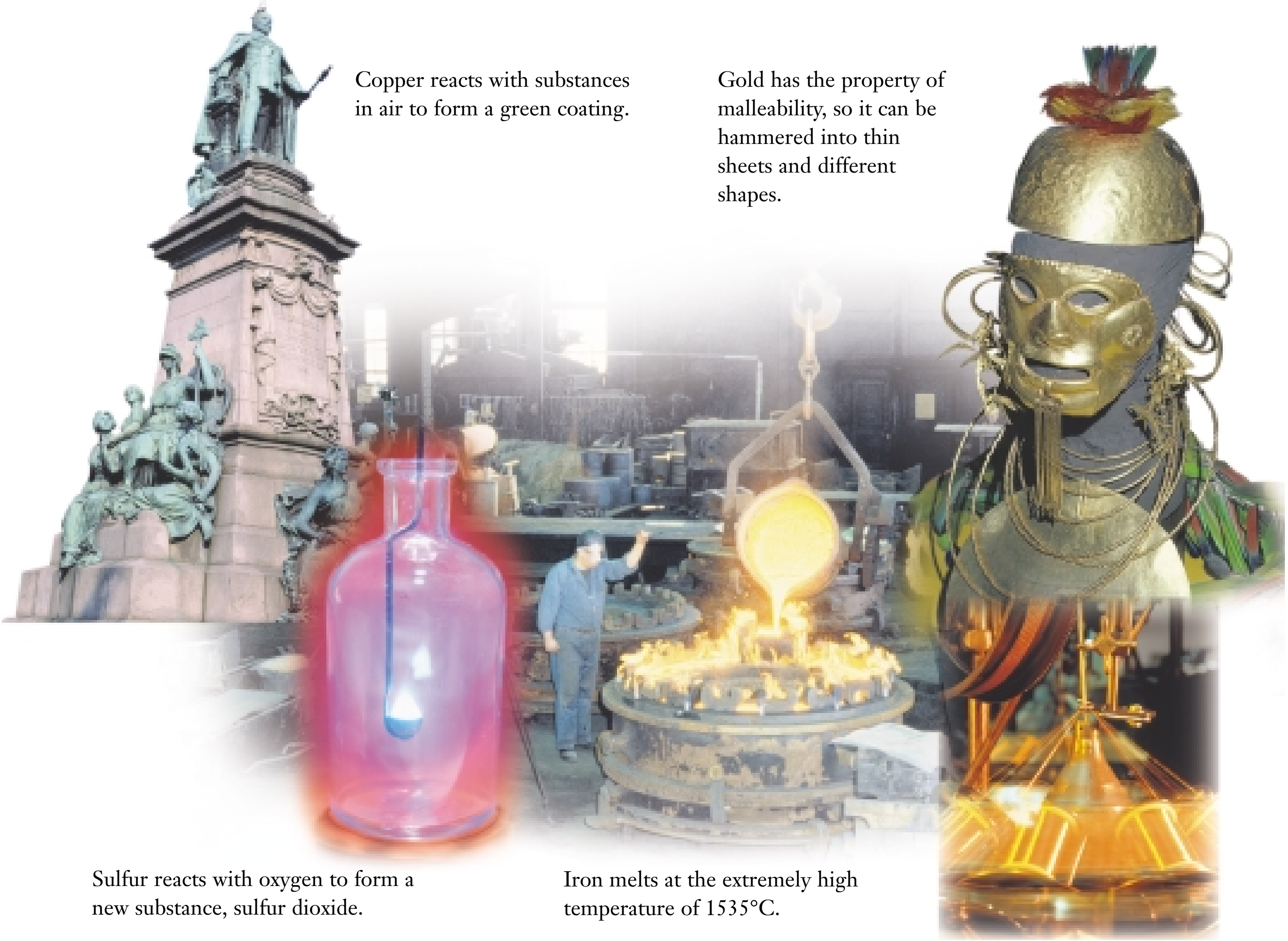
Physical properties are often further classified as either qualitative or quantitative (see Table 2.2 and Figure 2.11). A qualitative physical property is a characteristic of a substance that can be described but might not be measured (a quality). A quantitative physical property is a characteristic of a substance that can be measured numerically (a quantity).

Word CONNECT

Are you familiar with the words "ductility," "malleability," and "viscosity"? Use a regular or science dictionary or the Internet to discover their meanings. Write a definition of each in your notebook.

Table 2.2 Classification of Properties

Chemical Properties	Physical Properties	
	Qualitative	**Quantitative**
reacts with water	colour	melting temperature
reacts with air	texture	boiling temperature
reacts with pure oxygen	taste	density
reacts with acids	smell	viscosity
reacts with other pure substances	state	solubility
toxicity	crystal shape	electrical conductivity
stability	malleability	heat conductivity
combustibility	ductility	



Copper reacts with substances in air to form a green coating.

Gold has the property of malleability, so it can be hammered into thin sheets and different shapes.

Sulfur reacts with oxygen to form a new substance, sulfur dioxide.

Iron melts at the extremely high temperature of 1535°C.

A solid that is ductile can be stretched to form a wire.

Figure 2.11 Which of these properties are qualitative? Which are quantitative?

DidYouKnow?

Some of the first people to experiment with chemicals were the Egyptians. They observed the properties of chemicals and what happened when the chemicals interacted. One of their most famous technologies was the invention of mummification. To create a mummy, the religious leaders removed the soft organs and covered the body with a natural salt called natron. The salt was left on the body for 70 days to prevent decomposition. The body was then wrapped in cloth bandages, smeared with natural gum, and sealed in an air-tight container. The process was so effective that 3000-year-old mummies still have soft and elastic skin on the soles of their feet. Scientists have recently duplicated this process with authentic tools in hopes of learning more about mummification. Search the Internet to study more recent discoveries about this ancient technology.

TOPIC 2 Review

1. Name seven observations that may indicate a chemical change has occurred.

2. Which of the following are physical changes, and which are chemical changes? How do you know?

- **(a)** Sugar dissolves in water.
- **(b)** A steak is well cooked.
- **(c)** The filament of a light bulb glows when an electric current flows through it.
- **(d)** A piece of chalk is crushed.
- **(e)** A plant grows taller.

3. **Apply** Water and gasoline are both clear liquids at room temperature. Describe one physical property and one chemical property that might be used to distinguish between them.

4. **Thinking Critically** State two quantitative physical properties that change when antifreeze is dissolved in water.

5. **Thinking Critically** Examine the photograph of "the ice man" in Figure 2.12. Which physical and chemical changes do you think his remains have undergone in the past 5300 years? Do you think scientists established the age of the remains based on physical evidence or on chemical evidence? Why?

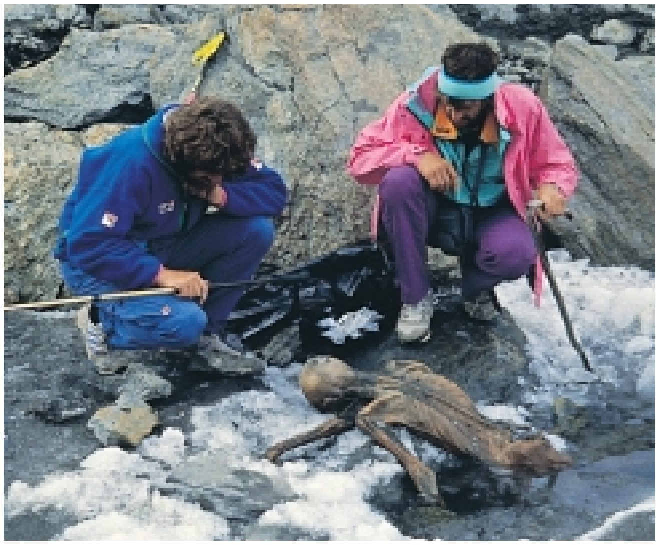


Figure 2.12 This is a photo of the oldest human remains ever found intact. A hiker found this body frozen in a glacier. Scientists established that the body is of a man who lived 5300 years ago.

TOPIC 3 What Are Elements?

Figure 2.13 Alchemists believed that "base" (meaning lower value) metals, such as lead and copper, could be changed into gold.

From very early times, people have wondered why matter behaves as it does. Ancient Greek philosophers thought that all matter was made out of fire, water, earth, and air. They called these four substances "elements." In their view, everything in the physical world was a combination of these four elements, and had varying properties of hotness, dryness, coldness, and wetness.

Hands-on investigations of matter were carried out for many centuries by people known as alchemists (see Figure 2.13). Part pharmacist, part mystic, alchemists practised their craft in Europe and the Middle East. Alchemists developed many useful procedures, such as distillation, and described the properties of many materials. They were secretive about their findings, however. Many invented their own shorthand symbols and secret codes so nobody else could understand their findings.

The current view of the elements began to develop several hundred years ago. Sir Francis Bacon (1561–1626) published a book arguing that science should be built on experimental evidence rather than on thought. Robert Boyle (1627–1691) recognized that elements could be combined to form compounds. Although he did not identify which materials were elements and which were compounds, his description laid the groundwork for our modern definition.

Bacon's ideas about scientific inquiry and Boyle's ideas about elements and compounds led to a widespread search for elements. Can you guess what kinds of discoveries followed?

DidYouKnow?

In Lavoisier's time it was not easy to make a living as a chemist. To support his family and his work in chemistry, Lavoisier took on a second job, working for a tax-collecting firm. However, there was a revolution in France, and people were angry about being taxed. Lavoisier was arrested, thrown into jail, and guillotined (beheaded). The world will never know what other secrets of chemistry Lavoisier could have uncovered.

Taking Matter Apart

How did scientists search for elements? They learned to take matter apart by ordinary chemical means until it would not break down any further. In this way, they were able to determine if a substance was a pure substance or a mixture.

During the seventeenth and eighteenth centuries, scientists worked with matter by heating, burning, mixing, and cooling. Antoine Lavoisier (1743–1794) was a pioneer in the field (see Figure 2.14). He defined elements as pure substances that cannot be decomposed (broken down) into simpler substances by means of a chemical change. We still use part of his definition today. Lavoisier identified 23 pure substances as elements.

One of Lavoisier's most successful techniques as an experimenter was his careful measurement of mass. He measured the mass of all the substances involved in a chemical change. These measurements helped him make accurate inferences about what was happening to the substances.

Lavoisier was one of the earliest chemists to use this "balanced" view of chemical changes. What Lavoisier observed during his experiments is what we now call the law of conservation of mass. You can repeat Lavoisier's observations in the next investigation.

The Law of Conservation of Mass

- In a chemical change, the total mass of the new substances is always the same as the total mass of the original substances.

Lavoisier's emphasis on measuring mass inspired other scientists to decompose compounds into elements and to measure the mass of each element. The results of their experiments led to the development of the **law of definite composition**.

The Law of Definite Composition

- Compounds are pure substances that contain two or more elements combined together in fixed (or definite) proportions.

Water is one example of the law of definite composition. Pure water always contains the elements hydrogen and oxygen combined together in the following proportions: 11% hydrogen and 89% oxygen by mass. These proportions hold true no matter where the water is obtained. Hydrogen peroxide, which is very different from water, contains the same two elements but in different proportions: 6% hydrogen and 94% oxygen. These proportions hold true for every sample of hydrogen peroxide.

Pure substances have constant composition, and therefore they also tend to have constant, unvarying properties. An unknown substance can be identified by measuring a property and comparing it to known values. For example, you might determine the density or melting point of an unknown metal and compare this value to the value found in a scientific table, such as Appendix C.

Figure 2.14 Marie-Anne Lavoisier was invaluable to her husband's research. She read the scientific articles in English and translated the articles she thought would interest her husband.

INQUIRY

INVESTIGATION 2-B

SKILL CHECK

Initiating and Planning

✹ Performing and Recording

✹ Analyzing and Interpreting

Communication and Teamwork

Mass and Chemical Change

The greatest challenge when investigating mass during a chemical change is to collect and measure all of the products. Be sure to carefully measure the mass of all the starting materials and all the products.

Question

What happens to mass during a chemical change?

Hypothesis

On the basis of what you know about the law of conservation of mass, state a hypothesis about the relationship of the mass of the reactants and the mass of the products.

Safety Precautions

- Handle the chemicals with care. If you spill copper (II) sulfate solution on your skin, wash it off immediately with cool water and inform your teacher.

Apparatus

balance
Erlenmeyer flask
rubber stopper for flask
graduated cylinder
scoopula

Materials

steel wool (2 cm^3)
copper (II) sulfate solution

Procedure

1. Obtain all supplies needed.
2. Put on safety goggles and aprons.
3. Make an observation chart like the one shown below.
4. Describe the reactants (copper [II] sulfate solution and steel wool) on your chart.
5. **Measure** the mass of the empty Erlenmeyer flask, stopper, and steel wool. **Record**.
6. **Measure** 20 mL of copper (II) sulfate solution in a graduated cylinder. Pour the solution into the Erlenmeyer flask. **Measure** the mass. **Record**.

	Starting Substances (Reactants)			Products
	copper (II) sulfate solution	steel wool	flask and stopper	
General Observations				
Mass				

⑦ **Calculate** the mass of the solution by subtracting the mass of the flask from the combined mass of the flask and solution. **Record**.

⑧ Drop the steel wool in the Erlenmeyer flask with the copper (II) sulfate solution. Quickly place the stopper on the flask. Gently swirl the flask so the solution completely covers the steel wool.

⑨ **Make observations** immediately and after 5 min.

⑩ **Measure** the mass of the entire system (flask, solution, stopper, etc.). **Record**.

⑪ Pour the remaining solution and steel wool into a special bucket provided by the teacher. You may need to use the scoopula to help retrieve the steel wool. **Do not pour the solution down the sink**. Chemicals poured down the drain will eventually end up in the water system or react with the pipes of the sewage system.

⑫ Clean all equipment and return it to the correct location.

Skill FOCUS

For tips on estimating and measuring, turn to Skill Focus 5.

Analyze

1. Did a chemical change take place? How do you know?
2. What was the mass of the starting materials in the reaction?
3. What was the mass of the products in the reaction?

Conclude and Apply

4. Do your observations support your hypothesis? Why or why not?
5. Experimental errors affect the accuracy of measurements and calculated results. These errors mainly come from limitations of the equipment used and from the design of the experiment. What were your sources of experimental error in this investigation?

Extend Your Skills

6. You could mix baking soda with vinegar to create carbon dioxide, water, and sodium acetate. If you started out with 5.6 g of baking soda and 4.9 g of vinegar, could you create 10.5 g of carbon dioxide gas? Why or why not? Design an investigation to check your answer. Carefully consider your selection of apparatus. How will the apparatus you use affect the accuracy of your results?

Career CONNECT

If you think that all chemists work in laboratories, think again! You can find chemists at work as teachers, technical writers, patent lawyers, geologists, dentists, food and drug inspectors, soil scientists, and X ray technicians. In what other fields is a background in chemistry necessary? Name five other professions in which a knowledge of chemistry is required. Then choose a career in chemistry that interests you and research the type of training needed for the job. Why does the job appeal to you? What would a chemist in your chosen occupation do on a day-to-day basis?

New Discoveries

By the nineteenth century, there was a new way to investigate matter. The "voltaic pile" — a device we now call a battery — was invented. The voltaic pile was not as convenient as today's dry cells, but it delivered a reliable supply of electric current. Scientists began using voltaic piles to pass electricity through water. They discovered hydrogen and oxygen gases were produced, and that the water level fell slightly. The scientists inferred that water had been decomposed into hydrogen and oxygen. The process of decomposing a chemical compound by passing an electric current through it is called **electrolysis** (see Figure 2.15). Scientists used electrolysis to isolate the elements potassium, sodium, magnesium, calcium, strontium, and barium.

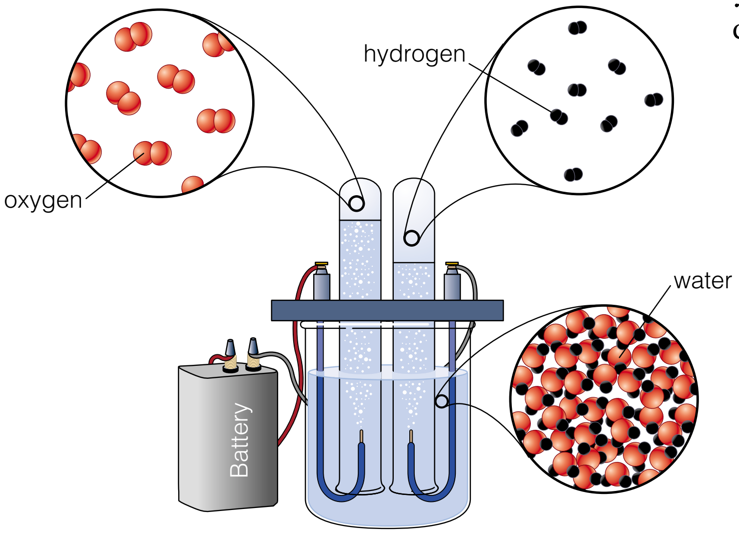


Figure 2.15 Water can be decomposed into the elements hydrogen and oxygen through the process of electrolysis. The two inverted test tubes were full of water when the experiment began. This drawing represents the results after about 10 min. Notice the volume of hydrogen produced is twice that of oxygen.

Find Out ACTIVITY

Collect the Elements

The most plentiful elements in Earth's crust include oxygen, silicon, aluminum, iron, magnesium, calcium, phosphorus, and sodium. What do you know about these elements? What would you like to know about them?

Procedure

Communication and Teamwork

1. Choose any three of the elements listed above and start an "element collection." Write the name of each element you have chosen on an index card, or choose another way to record what you learn. You may want to use a computer program.

2. Use print and electronic resources to research your chosen elements. Find out the following information for each of your elements: major physical properties, major chemical properties, who discovered the element and in what year, current uses, and interesting facts. Record the information you find. Include a photograph or drawing of the element. You might even be able to obtain a sample of the element.

3. Make a class list of recommended web sites or other resources that are a good source of information about the properties of elements.

4. Share your information with other students. You may wish to exchange cards, make a bulletin board display, or have a class presentation.

Extension

Add cards for other elements you learn about in this unit.

Dalton's Atomic Theory

In earlier studies, you used the particle model of matter to explain your observations of matter. However, the particle model cannot explain everything you have just learned about pure substances. It cannot, for example, explain what happens in the electrolysis of water. The properties of the compound, water, are different from the properties of the elements that make it up, hydrogen and oxygen. Therefore, the particles of water must be different from the particles of hydrogen and the particles of oxygen. The particle model of matter cannot account for particles of different substances combining or decomposing. John Dalton (1766–1844) introduced a new way of explaining chemical facts and laws in his atomic theory.

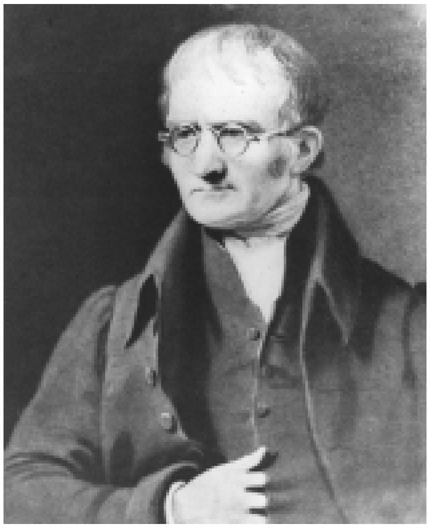


Figure 2.16 John Dalton

Dalton's Atomic Theory

- All matter is made up of small particles called atoms.
- Atoms cannot be created, destroyed, or divided into smaller particles.
- All atoms of the same element are identical in mass and size. Atoms of one element are different in mass and size from the atoms of other elements.
- Compounds are created when atoms of different elements link together in definite proportions.

Dalton's model (see Figure 2.17) uses the idea that elements are different because their "particles" (atoms) are different. This model led to more accurate definitions of element and compound.

An **element** is a pure substance made up of one type of particle, or atom. Each element has its own distinct properties and cannot be broken down into simpler substances by means of a chemical change. **Compounds** are pure substances that are made up of two or more elements chemically combined together. Compounds can be broken down into elements again by chemical means.

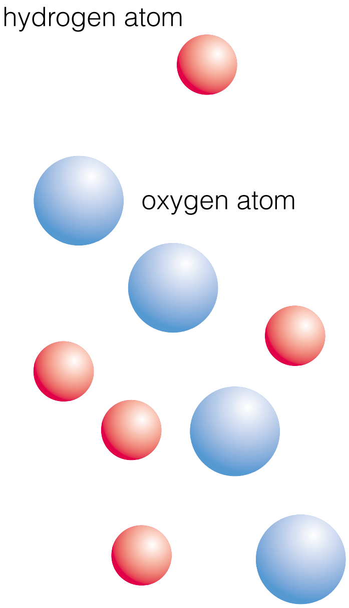


Figure 2.17 Dalton thought of atoms as billiard balls. He pictured water with equal numbers of smaller hydrogen and larger oxygen atoms.

DidYouKnow?

The history of chemistry is filled with tales of nearly simultaneous discovery. For example, the English scientist Joseph Priestley and the Swedish researcher Karl Wilhelm Scheele discovered oxygen at about the same time. Priestley published first and got all the credit for its discovery. The name "oxygen" was suggested by the French chemist Antoine Lavoisier.

Laws, Theories, Models, and Observations

In science, *laws* do not explain anything. Laws just *describe* and *summarize* what happens. Theories are imaginative ways to *explain why* something happens. During scientific experiments, scientists observe how matter behaves and reacts. Thousands of observations and hundreds of experiments are often made before a theory is accepted by scientists (see Figure 2.18).

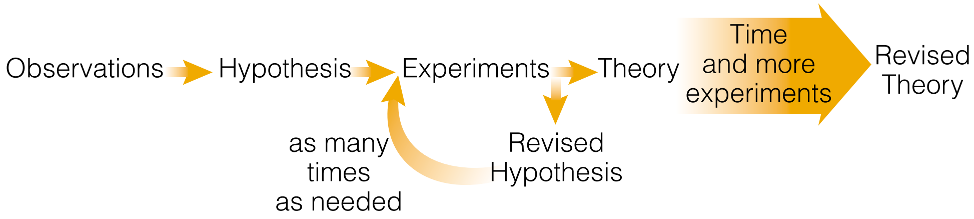


Figure 2.18 Many observations and experiments are needed before a hypothesis can become an accepted theory.

Scientific ideas may change over time as more evidence is gathered. Most of Dalton's atomic theory has stood the test of time. However, scientists have discovered that atoms are not the smallest particles. What do you suppose could be smaller than an atom?

Scientists who investigate the structure of the atom are faced with several challenges. How can they describe something they cannot see? What tests can reveal the inner workings of such tiny particles? Even with modern instruments, it is impossible to directly observe many aspects of atomic behaviour.

Scientific models help to picture structures or processes that cannot directly be seen. A good model can give a satisfactory explanation of what can be observed indirectly, and of what scientists can infer from these observations. Making inferences and constructing mental models requires practice and good reasoning skills.

It took many years and the work of scientists from many countries to devise the model of atomic structure in use today. Read the story of some of their discoveries on the next page. Notice how each scientist built on the achievements of other scientists in other parts of the world.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

The discovery of sub-atomic particles inspired many scientists to ask new questions. What else would *you* like to know about atomic structure? Make a list of three questions. Go to the web site above, and click on Web Links to find out where to go next. Research to find answers for your questions. If you have asked questions which science is not yet able to answer, speculate which discoveries are necessary in order for to establish the answers.

A Brief History of Atomic Models

British physicist J.J. Thomson studied rays in gas discharge tubes. He inferred that the rays were streams of negatively charged particles (**electrons**). Since atoms do not normally have a charge, Thomson reasoned there must also be positively charged particles in the atom. Thomson's model is sometimes called the "plum pudding" or "raisin bun" model, because he pictured the negatively charged electrons stuck in the positively charged mass like raisins in a bun. How was this model different from Dalton's "billiard ball" model in Figure 2.17 on page 111?

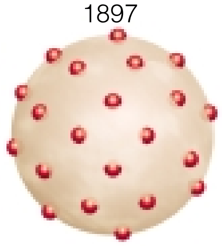


Figure 2.19A Thomson's "plum pudding" model

Ernest Rutherford was a scientist from New Zealand who worked for a while at McGill University in Montreal. He hypothesized that almost all of the mass of the atom was in the centre of the atom, which he named the **atomic nucleus**. The rest of the atom was mostly empty space occupied by very small electrons. The name **proton** was given to the positively charged particles making up the nucleus. Rutherford predicted there was another particle in the nucleus, along with the proton. Years later, British physicist James Chadwick proved him right. Chadwick discovered **neutrons**, uncharged particles in the nucleus with a mass slightly greater than protons.

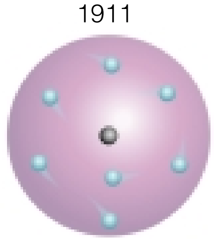


Figure 2.19B Rutherford's planetary model

The Danish physicist Niels Bohr studied with Rutherford. Both Bohr and Rutherford pictured the atom like a miniature solar system. Electrons rotated around the nucleus like planets rotating around the Sun. Although this model described hydrogen atoms, it was not useful in describing many of the atom's properties, so Bohr refined the model. He suggested that electrons move around the nucleus in fixed pathways called electron shells. The exact path and position of electrons could not be determined precisely, but their energy level could be determined.

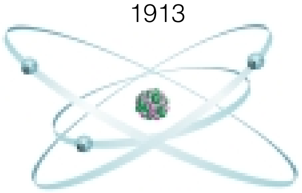


Figure 2.20A Bohr's atomic model

A further refinement to the model of atomic structure came through the work of French physicist Louis de Broglie, Austrian physicist Erwin Schrödinger, and many others. They agreed that electrons have distinct energy levels. They suggested that there was an area around the nucleus where electrons were most likely to be found. This region was called the electron cloud. In the electron cloud model, electrons are more likely to be closer to the nucleus than farther away. Schrödinger and de Broglie also developed a mathematical model. They suggested that the electron's behaviour could be described with equations very similar to those that describe waves. The answers to the equations give the probability of finding the electrons at certain places in the atom.

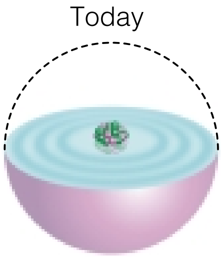


Figure 2.20B The electron cloud model

Across Canada

The metallic element cobalt can be used in the treatment of cancer. Canada led the world in this life-saving application, and Dr. Sylvia Fedoruk was one of its pioneers. She was chief medical physicist for the Saskatchewan Cancer Foundation for 35 years, and during this time she helped pioneer one of the world's first nuclear medicine scanning machines.

Sylvia was born in Canora, Saskatchewan. As a teenager, she loved sports, including hockey, basketball, volleyball, track, and curling. She has remained active in athletics, and in 1986 she was inducted into the Canadian Curling Hall of Fame. Sylvia has also been active in public life. From 1988 to 1994, she served as Lieutenant-Governor of Saskatchewan. She has promoted causes such as environmental conservation and excellence in education.

Dr. Sylvia Fedoruk

When Sylvia Fedoruk entered physics, there were few women in the field. When she became Saskatchewan's Lieutenant-Governor, she was the first woman in that office. What is her advice to young women of today? "Set personal goals. Dream of doing better than you ever thought you could. If you dream of accomplishing the impossible, you can!"

Off the Wall

How much of the atom is empty space? Consider this analogy: If the nucleus were the size of a grain of sand, the atom would have a diameter bigger than a football field.

Stretch Your Mind

Could there be particles even smaller than a proton or electron? What would such a particle do? What would it be called? Make some guesses about the answers to these questions. Then use the library or Internet to research "quarks" and Canadian Nobel Prize winner, Richard E. Taylor.

TOPIC 3 Review

1. How did methods of scientific inquiry help in the search for elements?
2. In your own words, write out the two laws mentioned in this topic.
3. Compare the particle model of matter and Dalton's atomic theory.
4. What is the difference between a law and a theory?
5. Define element and compound.
6. Name the scientists who discovered the proton, the electron, and the neutron. Why were these discoveries significant?
7. Copy and complete the following table to summarize what you know about the parts of an atom.

	Electron	Proton	Neutron
Charge			
Mass	very light	heavy	
Location			

8. **Apply** Air contains some carbon dioxide, but you exhale more carbon dioxide than you inhale. How would you design an experiment to confirm this statement?

Looking Ahead

Have you met with your group yet to design your End of Unit Investigation: Tough as Nails?

Wrap-up TOPICS 1-3

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

chemistry
caustic
homogeneous
heterogeneous
physical change
chemical change
law of conservation of mass
law of definite composition
electrolysis
Dalton's atomic theory
element
compounds
electrons
atomic nucleus
proton
neutrons

Reviewing Key Terms

1. In your notebook, write the difference between each of the following terms.
   (a) a heterogeneous mixture and a homogeneous mixture (1)
   (b) a physical change and a chemical change (2)
   (c) the law of conservation of mass and the law of definite composition (3)
   (d) an element and a compound (3)
   (e) an observation and a theory (3)

2. Copy the following sentences in your notebook, and fill in the blanks. (1–3)
   (a) If a substance has the ability to burn in oxygen, it has the property of _________. (2)
   (b) A homogeneous mixture can also be called a ______________________. (1)
   (c) A heterogeneous mixture can also be called a ______________________. (1)
   (d) A substance that cannot be broken down into simpler substances is an __________. (3)
   (e) The physical property of matter known as mass per unit volume is called ______. (2)

Understanding Key Concepts

3. What does WHMIS stand for? Why was the WHMIS system developed? (1)

4. List three examples of chemical changes and three examples of physical changes. (2)

5. Explain electrolysis. (3)

6. List the main points of Dalton's atomic theory. (3)

7. What is the difference between a compound and a mechanical mixture? Give an example of each. (3)

8. Make a sketch of the electron cloud model. Label the locations of the electrons, protons, neutrons, and atomic nucleus. (3)

9. When a fire burns a log of wood, the mass of the ashes left behind is much less than the mass of the original log. Is this an exception to the law of conservation of mass? Explain (3).

10. Several famous chemists have been discussed in Topics 1–3. Whose discovery did you find most interesting? Explain your choice. (1–3)

11. The element bismuth has a low melting point. How does this physical property help explain how the automatic sprinkler (shown below) works? (2)

The trigger in this overhead sprinkler is made from bismuth.

TOPIC 4 Classifying Elements

Figure 2.21 Marie Curie and her husband, Pierre, discovered the element radium. Marie invented the term “radioactivity.” She was the first scientist to be awarded two Nobel prizes. The element curium, discovered in 1944, was named in her honour.

New elements are still being discovered. How are elements named and sorted? Do some elements have similar properties?

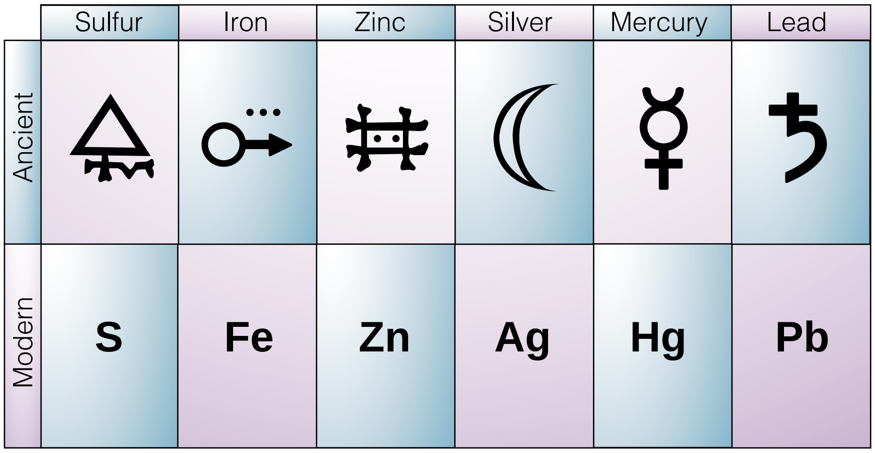
Element Symbols

The explosion of chemical knowledge during the nineteenth century could have led to confusion. The names of the elements came from many different sources. The first chemist to report a new element had the right to name it. For example, the chemist Marie Curie discovered the element polonium and named it after the country of her birth, Poland. Uranium was named after the planet Uranus. Einsteinium was named after the physicist Albert Einstein. Since it would be very difficult and time consuming to write names like these over and over again, a system of **element symbols** was developed. The system provided symbols for all the known elements. It also showed how to create symbols for any new elements that might be discovered. For example, the element symbol for lithium is Li. The symbol for boron is B, and the symbol for magnesium is Mg. You can find more examples of modern element symbols along with ancient symbols in Figure 2.22.

Although every language has its own way of saying and spelling the names of the elements, the symbols that are used to represent the elements are the same throughout the world. The next Find Out Activity will help you understand how this international system works.

Computer CONNECT

Find out how elements received their names. Research ten elements on the Internet or in the library. Use a spreadsheet program on a computer or a hand-drawn chart to create categories for the names given to the elements. A few possible categories are celestial names, geographical names, Latin names, and mineral names. Sort the elements into categories. Compare your categories and elements with those of your classmates.



	Sulfur	Iron	Zinc	Silver	Mercury	Lead
Ancient	🜍	♂	#	☾	☿	♄
Modern	S	Fe	Zn	Ag	Hg	Pb

Figure 2.22 Compare the ancient and modern symbols for these elements.

Find Out **ACTIVITY**

Symbols for Elements

How are symbols for elements determined?

Materials

Appendix C: Properties of Common Substances
your collection of element cards from Find Out Activity: Collect the Elements.

Procedure • Analyzing and Interpreting

1. Kal's body mass is 50 kg. Most of it (48 kg) is made up of just four elements: hydrogen (H), oxygen (O), carbon (C), and nitrogen (N). The symbols for these elements are in the parentheses. Use Appendix C: Properties of Common Substances to name four other elements that have the first letter of their name as their symbol.
2. About 1 kg of calcium is distributed throughout Kal's bones, teeth, and blood.
    - **(a)** What element already has the symbol C?
    - **(b)** Refer to Appendix C. What is the symbol for calcium?
    - **(c)** Name four other elements that have the first two letters of their name as their symbol.
3. Several element names begin with "b."
    - **(a)** The element boron can be used to make silicon computer chips conduct more electricity. Boron's symbol is B. Infer likely symbols for barium, beryllium, bismuth, and bromine. Check your ideas in Appendix C.
    - **(b)** In 1947 chemists in Berkeley, California, manufactured a new element and named it berkelium. Reread your answer for 3(a), than infer a likely symbol for berkelium. Refer to Appendix C. What is the symbol for berkelium?
4. The seven metals known to the ancients were called by their Latin names for centuries: *argentum* for silver, *aurum* for gold, *cuprum* for copper, *ferrum* for iron, *hydragyrum* for mercury, *plumbum* for lead, and *stannum* for tin.
    - **(a)** Infer possible symbols for these metals. Use Appendix C to check your inferences.
    - **(b)** Infer which metal was probably used for water pipes in ancient times. Explain how its name helped you make your inference.
5. The hair-thin wire in a light bulb is made of an element with two official names. Most of the world knows it as tungsten, but it is called wolfram in its country of discovery. Refer to Appendix C. Which name was used to create this element's symbol?

What Did You Find Out?

1. Add symbols on your element cards. Add to your collection any new elements you wish or any your teacher suggests.

Cool Tools

Bertram Brockhouse was born in 1918 in Lethbridge, Alberta. As a young boy he enjoyed fishing, dismantling radios, and reading popular electronics magazines. He spent many years researching the energy absorbed and released by atoms as they interact. In order to study the internal structure of atoms, he developed a neutron spectrometer. The neutron spectrometer used a beam of neutrons to show details of atoms thousands of times finer than had been revealed before. Bertram Brockhouse and an American, C.G. Shull, received the Nobel Prize in Chemistry in 1994 for their work. The neutron spectrometer is now used to investigate the internal structure of crystals, metals, gems, and rocks.

Different Kinds of Elements

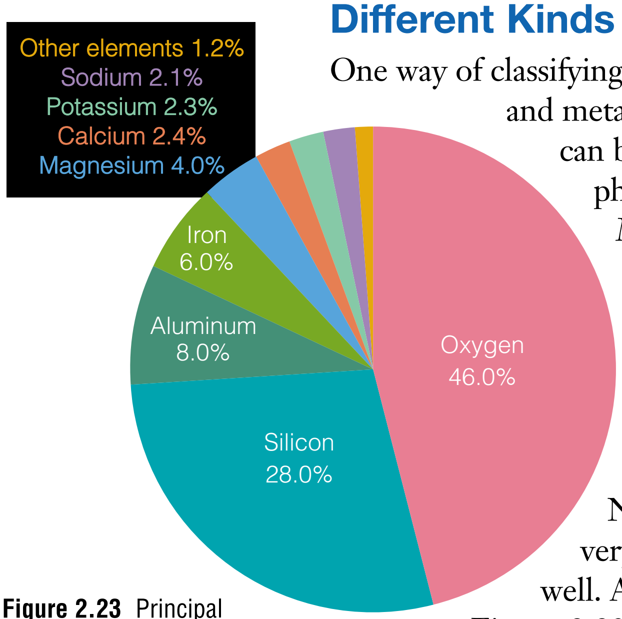


Figure 2.23 Principal elements in Earth's crust as measured by mass.

One way of classifying elements is to sort them into metals, non-metals, and metalloids. Metals conduct electricity and heat. They can be hammered into sheets and stretched into wires — physical properties called *malleability* and *ductility*. Metals have a shiny appearance or lustre, and all of them, except mercury, are solids at room temperature.

Non-metals, such as oxygen and sulfur, differ from metals in several ways. At room temperature, some are gases, some are solids, and only one is a liquid. The non-metals that are solid are brittle. Non-metals cannot be stretched into wires, are not very shiny, and do not conduct electricity or heat very well. Among the principal elements in Earth's crust (see Figure 2.23), the only non-metal is oxygen. Even when it is cooled to its liquid state, oxygen does not conduct electricity, and solid oxygen is very brittle.

Some elements, such as silicon, have properties that lie "in between" metals and non-metals. These elements are called metalloids, and they can have properties of both metals and non-metals. Silicon is the only metalloid found among the principal elements in the crust. In its most common compound, it appears as silicon dioxide. Although silicon can be made to conduct electricity, its properties lie in between those of metals and non-metals.

Metalloids are few in number. Non-metals are more numerous, but metals are the most numerous of these three kinds of elements. Compare the properties of the three different kinds of elements listed in Table 2.3.

Figure 2.24 At room temperature mercury is a liquid.

DidYouKnow?

Iron was one of the first elements put to use by humans thousands of years ago because it was easily extracted from iron ore by heat. The discovery and extraction of other elements occurred much more slowly. Over 112 elements are now known.

Table 2.3 Properties of Metals, Non-Metals, and Metalloids

	State at room temperature	Appearance	Conductivity	Malleability and ductility
Metals	• solids, except for mercury (a liquid)	• shiny lustre	• good conductors of heat and electricity	• malleable • ductile
Non-metals	• some gases • some solids • only bromine is liquid	• not very shiny	• poor conductors of heat and electricity	• brittle • not ductile
Metalloids	• solids	• can be shiny or dull	• may conduct electricity • poor conductors of heat	• brittle • not ductile

Find Out **ACTIVITY**

Identifying Metals

Teacher Demonstration

Scientists use the light given off by elements to determine the composition of the planets and stars. The brilliant colours you will see in flame tests can reveal metals in the compounds or mixtures that contain them.

Safety Precautions

Your teacher will demonstrate this activity.

Materials

Bunsen burner, heat-resistant pad, Q-tips™ or Nichrome™ wire, aqueous solutions of barium chloride, calcium chloride, potassium chloride, sodium chloride

Procedure ✷ Performing and Recording

1. Make a table like the one below to record the results of the tests. Give your table a title.

Compound	Colour of flame
barium chloride	

2. Put the Bunsen burner on the heat-resistant pad, light it, and adjust the air supply to produce a hot flame with a blue cone.
3. Dip one end of a Q-tip™ or Nichrome™ wire into one of the solutions, then hold the saturated tip so it is just touching the blue cone of the flame. You may need to hold the Q-tip™ or Nichrome™ wire in this position for as long as 30 s. Record the colour of the flame.
4. Repeat step 3 for the other solutions, and record the colours of the flames.

What Did You Find Out? ✷ Analyzing and Interpreting

1. How do you know that the colour of the flame is due to the metals and not to something else in the solutions?
2. If you saw a fireworks display that was green, what metal might be present?

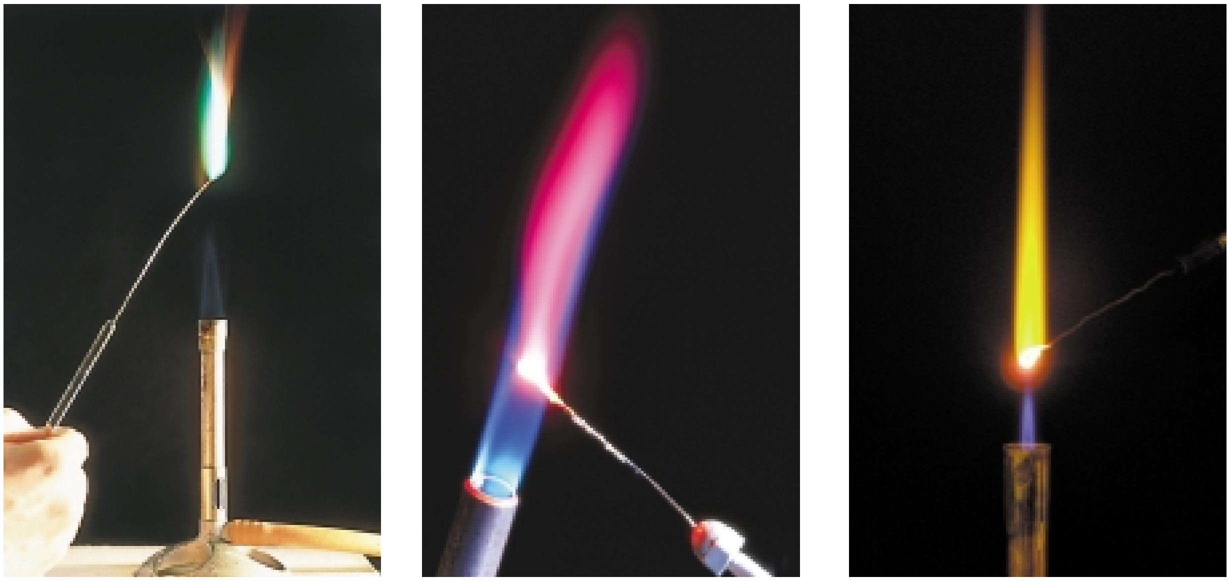


Figure 2.25 Flame tests for three different elements are shown. Discuss these pictures as a class. Which elements burn with these colours?

Figure 2.26 Stainless steel braces are made of carbon, nickel, and iron. Teeth will straighten due to the strength of the elements.

Chemical Families

Elements are everywhere ... even in your mouth. Which elements can you see at work in Figure 2.26?

The metals used in the mouth need to be unreactive with mild acids and with gases that are inhaled and exhaled. Gold, silver, and copper can be mixed and will not react readily with oxygen. If you need a new tooth to be made and moulded to your mouth, it might be made of a combination of gold, silver, and copper.

The term **chemical family** is used to describe a group of related elements that have similar properties. Gold, silver, and copper were once used to make coins and are often referred to as coinage metals. In the next activity you will consider their chemical properties.

Find Out ACTIVITY

A Chemical Family

The members of a chemical family are not identical, but they do have certain features in common. Scan the table below, and answer the questions that follow it.

Property	Elements				
	Aluminum (Al)	**Copper (Cu)**	**Gold (Au)**	**Iron (Fe)**	**Silver (Ag)**
effect of acid on cleaned, bare, pure metal	reacts with acid; hydrogen gas released	unreactive with most acids	unreactive with most acids	reacts with acid; hydrogen gas released	unreactive with most acids
compound formed with oxygen?	readily	not readily	not readily	readily	not readily
malleability	very malleable	very malleable	highly malleable	malleable	very malleable
electrical conductivity	very good	second best of all metals	excellent	good	best of all metals

Procedure ✷ **Analyzing and Interpreting**

Use the word "pattern" in your answers to the following questions.

1. The coinage metals — copper, silver, and gold — are considered to be a chemical family. List three arguments to explain why.
2. **(a)** List arguments in favour of including aluminum in the family of coinage metals.
   (b) List arguments against including aluminum.
3. **(a)** List arguments in favour of including iron in the family of coinage metals.
   (b) List arguments against including iron.
4. Do you think aluminum belongs to the same chemical family as iron? List arguments for and against.

Alkali Metals

Most metals are reactive. However, alkali metals are so reactive that many of them require special storage (see Figure 2.27). Why are they so reactive? There is a tendency for electrons to be found in pairs. Each alkali metal has an unpaired electron and tends to get rid of the electron by forming a compound. A list of alkali metals is provided below. You can see pictures of alkali metals in Figure 2.35, the Pictorial Periodic Table, on pages 132-133.

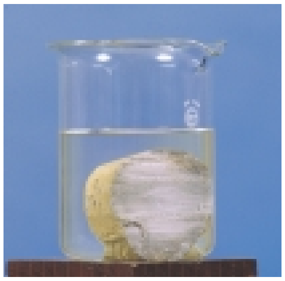


Figure 2.27A *(left)* Freshly cut sodium is bright and shiny, but only while stored in oil.

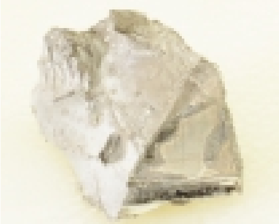


Figure 2.27B After a few minutes' exposure the surface of the sodium has dulled because the sodium atoms have reacted with oxygen from the air.

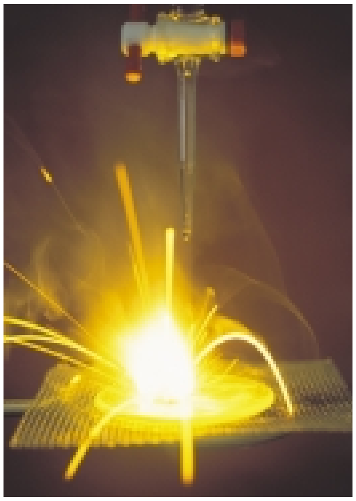


Figure 2.27C When a small lump of sodium is dropped into water, a vigorous reaction takes place.

Alkali metals (very reactive)
lithium Li
sodium Na
potassium K
rubidium Rb
cesium Cs
francium Fr

Alkaline earth metals (fairly reactive)
beryllium Be
magnesium Mg
calcium Ca
strontium Sr
barium Ba
radium Ra

Alkaline Earth Metals

Another chemical family is the alkaline earth metals. Their name comes from early chemists who thought anything that was insoluble in water and unchanged by heat was one of the "earth" elements. The alkaline earth elements react fairly vigorously with some substances, but they are not as reactive as the alkali metals. For example, magnesium reacts with water but less vigorously than sodium does. A list of alkaline earth metals is provided above. You can see pictures of these metals in Figure 2.35, the Pictorial Periodic Table, on pages 132-133. You can investigate the reactivity of metals in the next investigation.

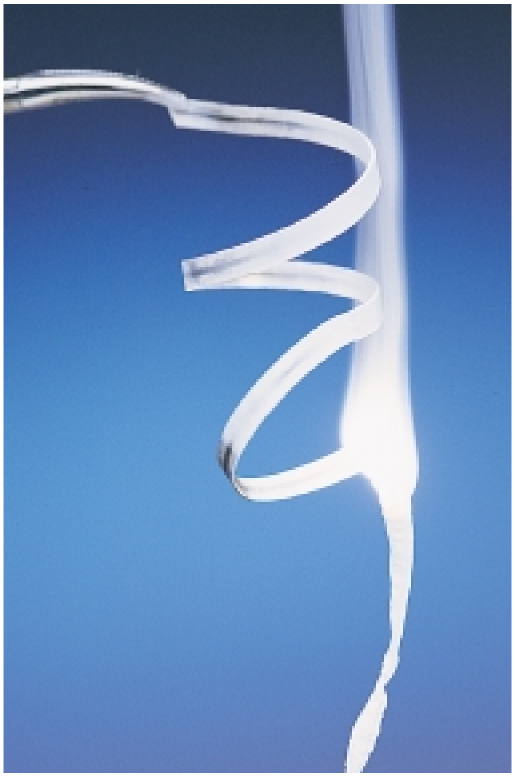


Figure 2.28 When magnesium burns, it gives off intense white light and white smoke. Since magnesium burns in carbon dioxide, what kind of fire extinguisher can be used to put out a magnesium fire?

INQUIRY

INVESTIGATION 2-C

SKILLCHECK

- Initiating and Planning
- ✸ Performing and Recording
- ✸ Analyzing and Interpreting
- ✸ Communication and Teamwork

Ready to React

Scientists have been able to arrange metals in order of activity. Metals high on the activity series table react readily. Metals lower on the table react less readily. A metal will replace any metal beneath it in the table during a reaction. This type of reaction is called a displacement reaction. Notice that copper, silver, and gold are at the bottom of the list. These elements are relatively inactive, so they often occur in Earth as veins of relatively pure elements. Most other metals are more active and occur as compounds.

Question

How do you recover the solute from a solution using an active metal?

Hypothesis

As a group, make a hypothesis about what will happen when aluminum foil is placed in a solution of copper (II) sulfate and hydrochloric acid. Refer to the Activity Series of Metals table to help you make the hypothesis.

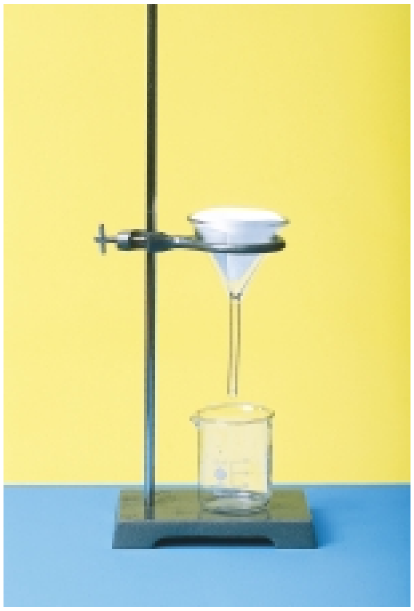
Activity Series of Metals	
lithium	Most active
potassium	
barium	
calcium	
sodium	
magnesium	
aluminum	
zinc	
iron	
nickel	
tin	
lead	
(hydrogen)	
copper	
mercury	
silver	↓
gold	Least active

Apparatus

triple beam or electronic balance
mortar and pestle
scoopula
2 400 mL beakers
10 mL graduated cylinder
stirring rod
funnel
retort stand
ring clamp or burette

Materials

copper (II) sulfate
water
hydrochloric acid (3 mol/L)
box of baking soda for spilled acid
aluminum foil
filter paper



Safety Precautions

- Don't let the hydrochloric acid touch your skin. If you accidentally spill it on your skin, wash it off immediately with lots of cool water and inform your teacher.

Day One

Part 1

Procedure

① Make an observation chart to use for this investigation.

② **Measure** about 2.5 g of copper (II) sulfate. Place the copper (II) sulfate in the mortar and grind until you have a fine powder.

③ Use the scoopula to scoop the powder into a 400 mL beaker.

④ Add 30 mL of water to the copper (II) sulfate in the beaker. Stir until the powder has dissolved. **Observe** and **record** your observations on the chart.

⑤ Add 5 mL of hydrochloric acid (3 mol/L) to the beaker. **Record** your observations. **CAUTION:** Handle the acid and anything that it touches with caution. Be sure to rinse out the graduated cylinder when you are done. Neutralize any spills with baking soda. Wipe up any spills immediately. Wash your hands after cleaning spills.

⑥ Cut a small piece of aluminum foil (4 cm × 4 cm). **Measure** the mass of the foil and **record**.

⑦ Roll the foil around the stirring rod. Place the foil in the beaker of copper (II) sulfate and acid. Gently submerge the foil in the solution with the stirring rod. **Observe** carefully. Touch the outside bottom of the beaker with your hand. **Record** your observations.

Part 2

Procedure

① **Measure** and **record** the mass of the filter paper.

② Fold a piece of filter paper and place it in the funnel. Dampen the filter paper with water so it will stay in place.

③ Attach the funnel to a retort stand with a ring clamp or burette clamp. Place an empty beaker under the funnel.

④ Carefully pour the acidic solution through the filter paper. Do not let the solution pour over the sides of the filter paper. If particles remain in the beaker, add a small amount of water to rinse them into the filter paper.

⑤ Pour 20 mL of water through the residue on the filter paper to get rid of any excess acid.

⑥ Unfold the filter paper. Place the filter paper and residue in a safe place to dry. Rinse stirring rod, funnel, and beakers to remove acid.

Day Two

⑦ **Measure** the mass of the residue and filter paper. **Record**. Subtract the mass of the clean piece of filter paper. **Record**.

⑧ Place the residue in the container provided by your teacher.

Analyze

1. What colour was the first copper (II) sulfate solution you made?
2. What happened to the solution when you added hydrochloric acid?
3. Was there a chemical or physical change in this experiment? Give reasons for your answers.
4. What substance was recovered in this investigation? How do you know?

Conclude and Apply

5. Compare the mass of the original metal (aluminum) to the mass of the residue. What conclusion can you draw based on your evidence?
6. What would happen if you added more aluminum foil to the beaker after the reaction was complete?

Extension

7. How could displacement reactions be used in mining metals? Research in the library or on the Internet. Present your answer in the form of a flowchart.

Word CONNECT

Look up "argon" in a dictionary, and find out about the Greek word it comes from. Why is "argon" a good name for an unreactive gas?

Noble Gases
helium He
neon Ne
argon Ar
krypton Kr
xenon Xe
radon Rn

DidYouKnow?

Before 1963, chemistry textbooks claimed that the noble gases were entirely inert — that is, they would never form chemical compounds. Then Canadian chemist Neil Bartlett startled the scientific world by preparing noble gas compounds in a laboratory at the University of British Columbia. The methods he used to rearrange the electrons were not exceptionally difficult, but the compounds proved to be unstable. The noble gas atoms are definitely more stable when uncombined.

The Noble Gases

Chemists find the noble gases interesting because they are so unreactive. As you will find out, unreactivity can be a very useful property.

Consider an ordinary light bulb. If the slightest leak allows air to get inside the glass covering, the filament will burn out in a bright flash of light and the bulb will go dark. Exposure to oxygen makes the tungsten filament burn. The filament burns because electrons of hot tungsten atoms are transferred to nearby oxygen atoms. If oxygen is excluded, however, tungsten cannot react. Modern light bulbs are usually filled with argon, an unreactive gas, to keep the tungsten filament from burning out. Argon is a noble gas.

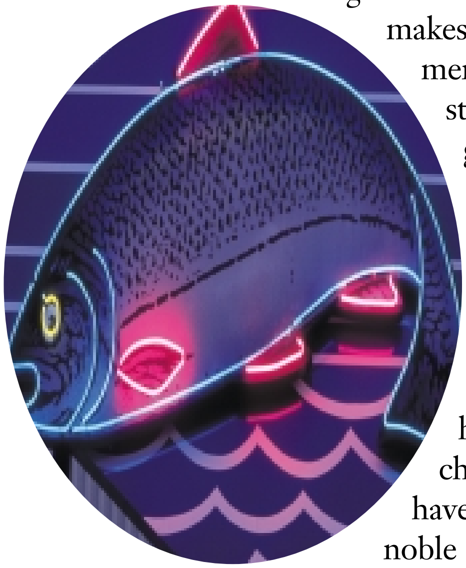


Figure 2.29 Each colour in this advertising sign is caused by a different noble gas. Argon produces the blue colour and helium produces yellow-white. Lighting designers can obtain more colours by adding other substances to the gas mixture. Why do different gases produce different colours?

Numerous laboratory experiments have confirmed that all noble gases are chemically "stable." Noble gases do not have any unpaired electrons. Therefore, noble gases are highly unlikely to take part in a chemical change. In fact, only the very largest noble gas atoms can be made to react chemically at all. Even when they do react, their compounds soon decompose, allowing the noble gas to separate into single atoms again.

A list of noble gases is provided on this page. Locate the noble gases in Figure 2.35, the Pictorial Periodic Table on pages 132–133.

The Halogens

Halogens are naturally found in the form of compounds because halogen atoms react vigorously with almost every other element. Halogens, like alkali metals, have an unpaired electron. However, halogens have a tendency to gain an available electron when they form compounds. Even the least reactive halogens are extremely corrosive and harmful. There are many common uses for halogen compounds. For example, fluorine compounds are added to some toothpastes and some city water supplies. The compounds help prevent decay by making tooth enamel stronger and more resistant to decay. Read the list of halogens on the next page, then locate their pictures in figure 2.35, the Pictorial Periodic Table on pages 132–133.

Halogens (very reactive)
fluorine F
chlorine Cl
bromine Br
iodine I
astatine At

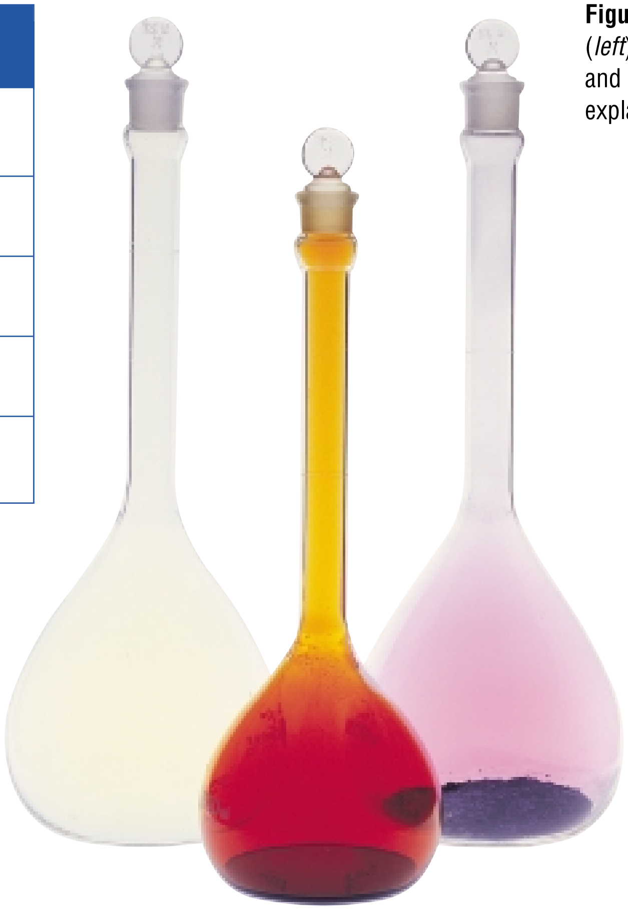


Figure 2.30 At room temperature chlorine (*left*) is a gas, bromine (*centre*) is a liquid, and iodine (*right*) is a solid. Can you explain why?

Word CONNECT

Three of the halogens — chlorine (Cl), bromine (Br), and iodine (I) — derive their names from Greek words that describe one of their properties. Chlorine comes from *chloros*, describing the greenish-yellow colour of the gas. (You may also recall the word "chlorophyll" from your earlier science studies. What colour is chlorophyll?) *Iodeides* means violet-coloured, which describes the vapour of iodine. Look up "bromine" in a dictionary. Which Greek word is it derived from? What could you guess about bromine vapour?

TOPIC 4 Review

1. In the eighteenth century, 18 elements were discovered. Their symbols are Co, Pt, Ni, H, N, Cl, Mn, O, Mo, Te, W, U, Zr, Ti, F, Sr, Be, and Cr.
   (a) List these symbols. Write one symbol on each line.
   (b) Use Appendix C to write the name for each element beside its symbol.
2. (a) Give an example of a metallic element.
   (b) Give an example of a non-metallic element.
   (c) Give an example of a metalloid element.
3. What are four physical properties used to compare metals, non-metals, and metalloids?
4. Describe the physical and chemical properties of the "coinage metals" that make them suitable for use in coins.
5. Briefly describe some uses of the noble gases mentioned in this Topic. What chemical properties do they have in common?

Math CONNECT

Consider the lists you made in question 1. What is the total number of elements in the list? How many of these elements are metals? (Hint: Consult Appendix C.) Express the number of metallic elements as a percentage of the total number of elements in the list.

TOPIC 5 The Periodic Table

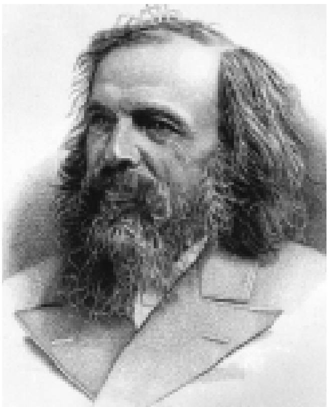


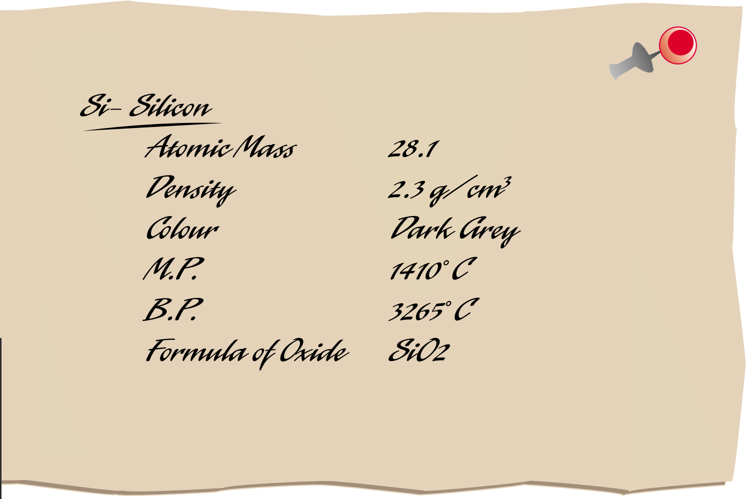
Figure 2.31 Dmitri Ivanovich Mendeleev was born in Siberia, the youngest of 17 children.

By the 1850s, chemists had identified a total of 58 elements, and nobody knew how many more there might be. Chemists attempted to create a classification system that would organize their observations. The various "family" systems were useful for some elements, but most family relationships were not obvious. What else could a classification system be based on?

By the 1860s several scientists were trying to sort the known elements according to atomic mass. **Atomic mass** is the average mass of an atom of an element. According to Dalton's atomic theory, each element had its own kind of atom with a specific atomic mass, different from the atomic mass of any other elements. One scientist created a system that was so accurate it is still used today. He was a Russian chemist named Dmitri Mendeleev (1834–1907).

Mendeleev Builds a Table

Mendeleev made a card for each known element. On each card, he put data similar to the data you see in Figure 2.32.



Si– Silicon

Atomic Mass	28.1
Density	2.3 g/cm³
Colour	Dark Grey
M.P.	1410° C
B.P.	3265° C
Formula of Oxide	SiO2

Figure 2.32 The card above shows modern values for silicon, rather than the ones Mendeleev actually used. His values were surprisingly close to modern ones. The atomic mass measurement indicates that silicon is 28.1 times heavier than hydrogen. You can observe other properties of silicon in Figure 2.33.

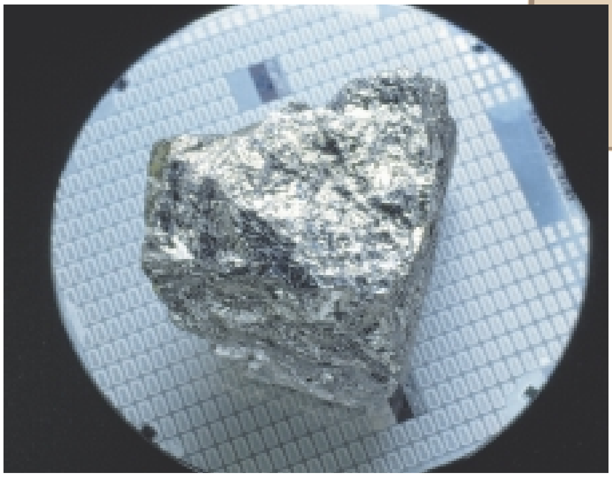


Figure 2.33 The element silicon is melted and formed into a crystal. The crystal is then sliced into thin wafers to produce electronic devices such as these microprocessor chips.

Mendeleev pinned all the cards to the wall, in order of increasing atomic mass. He "played cards" for several months, arranging the elements in vertical columns and horizontal rows. In the next activity, you will model Mendeleev's method.

Find Out ACTIVITY

Chemical Solitaire

In this activity, you will arrange element cards in groups according to their atomic mass and other properties.

Materials

sheet of property cards for fictional elements (provided by your teacher)

scissors

Procedure ✷ Analyzing and Interpreting

1. Cut the sheet into separate cards.
2. Line up the cards in order of increasing atomic mass.
3. Examine the cards to look for properties that are similar enough to justify placing certain elements above or below each other in a family. Find an arrangement that also keeps the cards in order by atomic mass.
4. Compare your arrangement with that of other students. Are there any refinements you can make to your arrangement? If so, record your new arrangement.

What Did You Find Out?

1. Which cards probably represent metallic elements? Which probably represent non-metallic elements? Give reasons for your opinions.
2. Which elements are solids? Which are liquids? Which are gases? Explain how you know.
3. Which of your arrangements do you think is the best? Why?

Extensions

4. How long did it take you to classify these elements? Mendeleev had to classify 63 elements. How long do you think it took him?
5. Where do you think Mendeleev got the data he wrote on his cards? (Hint: Do you think he performed all the experiments himself to get the data?)

Putting the Elements in Order

When Mendeleev arranged the elements in order of increasing atomic mass, he found that the properties of the elements repeated at definite, or periodic, intervals. The eighth element in his arrangement (sodium) had properties similar to the first (lithium), and the fifteenth element (potassium) had properties similar to the eighth. Therefore the first, eighth, and fifteenth elements made up a chemical family. The pattern Mendeleev discovered became known as the periodic table.

Mendeleev left gaps in his table, blank spaces predicting the existence of elements not yet found or even suspected by other chemists. He even predicted properties of these unknown elements, which spurred on other scientists to prove or disprove his predictions.

How did Mendeleev's table make it possible for him to predict the properties of other, still undiscovered, elements? Mendeleev noted which families had spaces. He inferred that the missing elements would have properties similar to those of other members of the family. Two examples, gallium and germanium, are famous for having been discovered shortly after Mendeleev predicted their existence and physical properties (see Figure 2.34). The discovery of gallium and germanium was a remarkable example of experimental evidence confirming a scientific prediction.

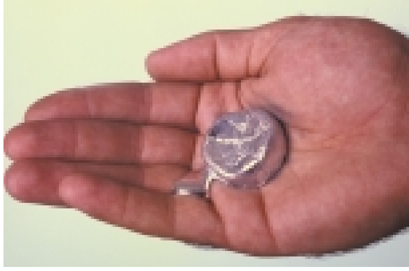


Figure 2.34 The melting point of gallium is so low that it will melt in a person's hand.

Mendeleev had noticed a periodic relationship between increasing atomic mass and chemical properties of elements. His work provided a logical organization for a huge amount of data about the elements, but no one could explain why the elements showed their amazing periodicity.

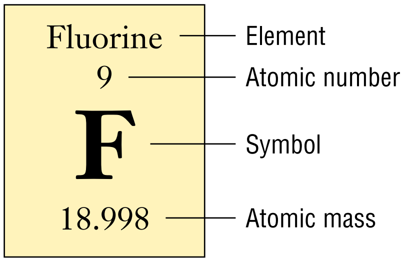
By about 1915, chemists and physicists had developed models of atomic structure, and it became clear that atomic structure was the key to explaining the periodicity of chemical properties. The periodic table was therefore reorganized with a focus on atomic structure rather than just atomic mass. The changes were surprisingly few. The resulting modern periodic table is based on a special number for each element, called its atomic number.

The **atomic number** is the number of protons an element has in its nucleus. For example, the atomic number of fluorine is nine, indicating that there are nine protons in the nucleus. The atomic number of oxygen is eight, so it has eight protons in the nucleus. Since all atoms are neutral, their positive and negative charges must be balanced. In other words, atoms contain an equal number of electrons and protons. How many electrons must be in a fluorine atom? How many electrons must be in an oxygen atom?

DidYouKnow?

The number of protons in an atom determines what element it is. For example, all atoms that contain three protons in the nucleus are atoms of lithium.

The atomic mass, atomic number, and symbol for an element are sometimes represented in a periodic table like this:



Mass Number

Chemists use another number, called the **mass number**, to give the total number of protons and neutrons in an atom.

$$\begin{array}{rl} & \text{number of protons} \\ + & \text{number of neutrons} \\ \hline = & \text{mass number} \end{array}$$

If you know the atomic number and mass number, you can calculate the number of neutrons by subtracting:

$$\begin{array}{rl} & \text{mass number} \\ - & \text{atomic number} \\ \hline = & \text{number of neutrons} \end{array}$$

The mass number of fluorine is 19. If you subtract its atomic number of nine, you can conclude that an atom of fluorine must contain ten neutrons.

Math CONNECT

Calculate the number of neutrons in the following elements. The approximate mass number is given for each in parentheses: carbon (19), neon (20), sodium (23), and magnesium (24).

THINK & LINK

INVESTIGATION 2-D

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Meet the Modern Periodic Table

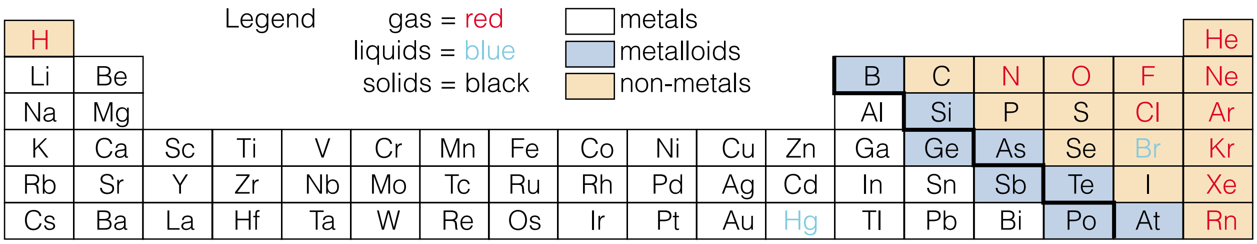
Part 1

Every Element Has Its Own Number

Think About It

The periodic table below is simplified. It shows the general shape of the table and includes symbols for the elements, arranged in order of their atomic number. It also indicates which elements are gases, which are liquids, and which are solids at room temperature.

Notice the "staircase" on the right-hand side. The metals are found to the left of the staircase. The non-metals are found to the right (except for hydrogen). The metalloids are on either side of the staircase.



Legend
gas = red
liquids = blue
solids = black

☐ metals
🟦 metalloids
🟧 non-metals

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

A simplified view of part of the modern periodic table

What to Do

① An element's position in the periodic table is determined by its atomic number. The numbering system begins with hydrogen (H), atomic number 1, in the upper left-hand corner and moves from left to right. The numbers skip any blank space in between, so helium (He) has atomic number 2. The numbers then jump back to the left again, so lithium (Li), atomic number 3, is next.

Make a copy of this simplified periodic table and record these atomic numbers on it.

② Infer and record the atomic numbers for beryllium (Be) and boron (B). Do the same for the rest of this horizontal row, from carbon (C) to neon (Ne).

Analyze

1. Which element in each pair below has the larger atomic number? Explain how you know.

(a) carbon (C) or silicon (Si)
(b) silicon (Si) or phosphorus (P)
(c) beryllium (Be) or sodium (Na)

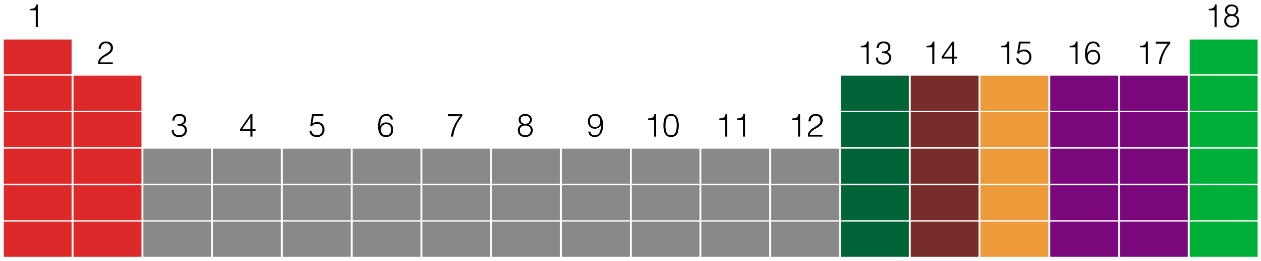
CONTINUED ▶

Part 2

Every Element Is Part of a Group

Think About It

Chemists call each vertical column in the periodic table a group. Chemical families are located in the same group.



How groups appear in the periodic table

What to Do

Combine information from the simplified periodic table in Part 1 and the diagram above to answer the following questions.

❶ There are 18 groups in the periodic table, as you can see by counting across the top of the diagram. Locate the elements in the second group in your simplified periodic table.

❷ Record the symbols for these elements in a vertical list. Which element in the list has the largest atomic number?

❸ Which element would you expect to have the greatest atomic mass? Why?

Analyze

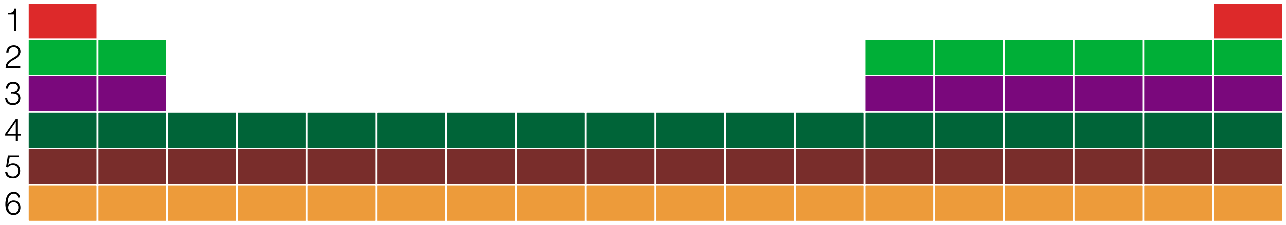
1. List the symbols, and as many names as you can, of the other elements that are found in the same group as the elements below.
   (a) aluminum (Al)
   (b) potassium (K)
   (c) lead (Pb)
2. Locate the elements copper (Cu), silver (Ag), and gold (Au) on your simplified periodic table. Are they in the same group? Is this what you expected?
3. List these chemical families in your notebook: alkali metals, alkaline earth metals, noble gases, and halogens. Which group number is each family? (Refer to pages 121–125 if you need help.)

Part 3

Every Element Is Part of a Period

Think About It

The horizontal rows of the periodic table are called **periods**. There are seven periods, although these simplified diagrams show only six. You probably noticed the empty spaces in the middle of Periods 1, 2, and 3. There is a reason for these spaces. For example, even though helium has an atomic number 2, it does not belong next to hydrogen. Helium belongs in the group having similar chemical properties — the noble gases. Mendeleev and other scientists of his time were aware of these gaps. However, the explanation for the gaps did not come until much later when scientists began to explore the inner structure of the atom.



How periods appear in the periodic table

What to Do

Combine information from the simplified periodic table in Part 1 and the diagram above to answer the following questions.

① Record the symbols of the elements in Period 2 so they are stretched out horizontally across a page. Place the symbols of the elements in Period 3 directly beneath them, as they appear in the table.

② Most of the elements are solids at room temperature. In your simplified periodic table, elements that are liquids at room temperature are in blue. Circle all of the liquids on your periodic table. Do any of them appear in Period 2 or Period 3?

③ Elements that are gases at room temperature are in red. Mark all of these on your periodic table with a highlighter. You will find gases in both Period 2 and Period 3. For each gas in Period 2, is there a corresponding gas underneath it (in the same group) in Period 3? Period 4? Period 5?

Pause & Reflect

Can survival depend on a knowledge of the elements? Primo Levi was born in Italy and trained as a chemist. During World War II he was arrested and sent to a concentration camp. Levi attributes his survival to his passion for chemistry. He wrote a book called *The Periodic Table* in which chemical elements are metaphors for human experience. In the chapter called “Carbon,” Levi observes how all living things are united as he follows a carbon atom through rocks, leaves, milk, blood, and muscle. He uses the element hydrogen to explain the explosive nature of his life as a teenager. Levi states, “Chemistry is the art of separating, weighing, and distinguishing. These are also useful exercises for people to perform and use when trying to give body to their own imagination.” What do you think Levi means in this quotation? Is there some way you could use the properties of an element as a metaphor?

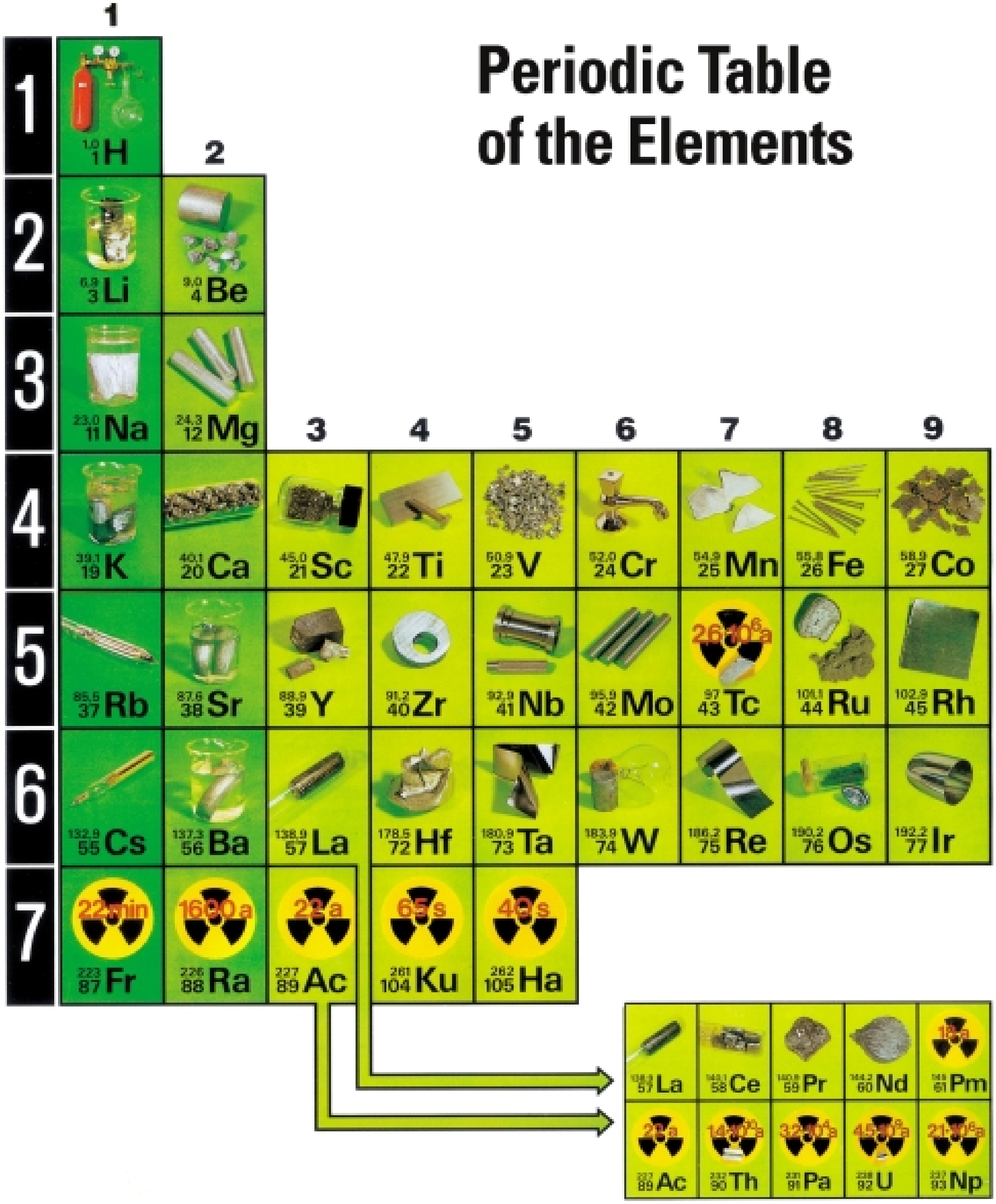
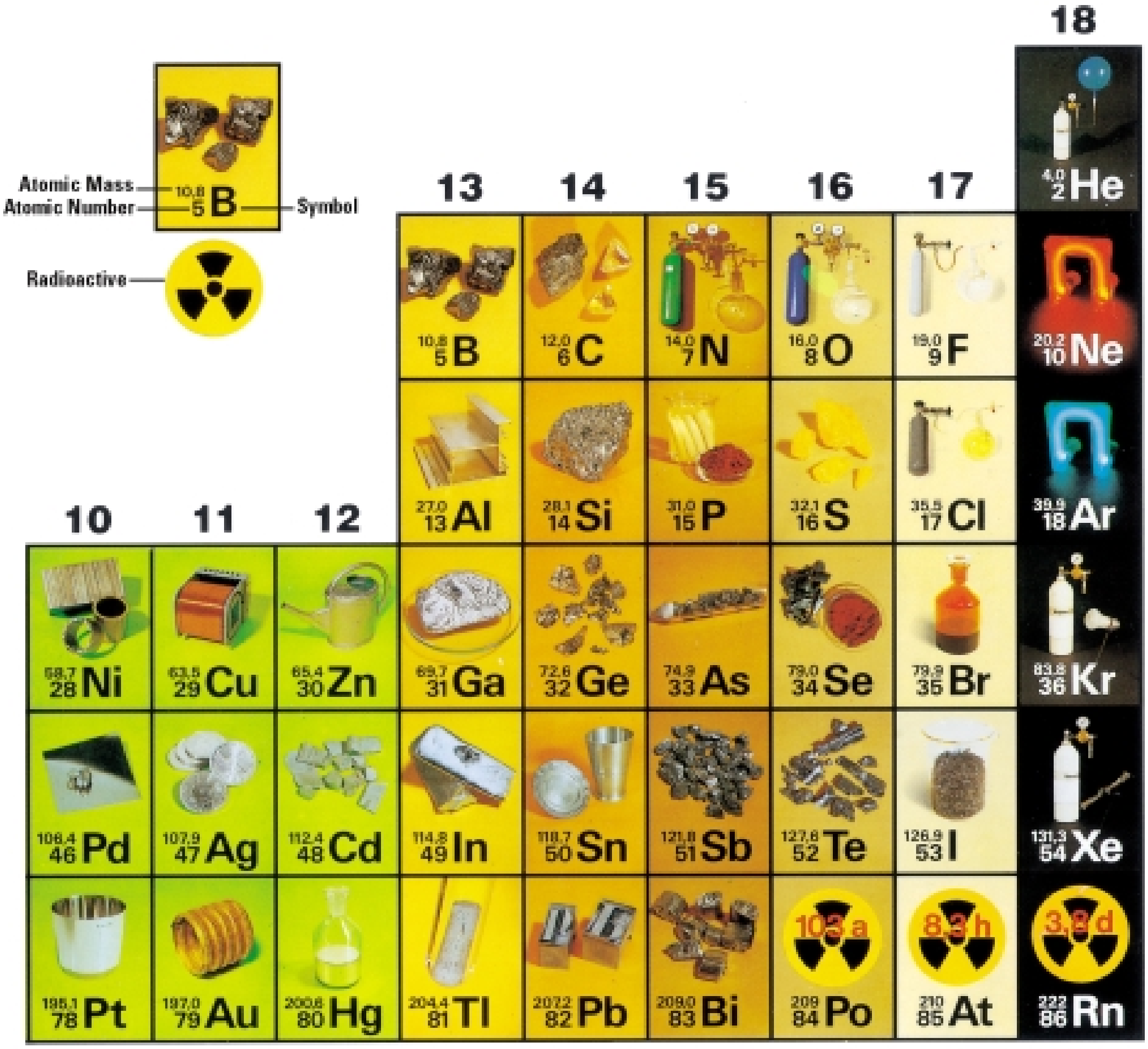
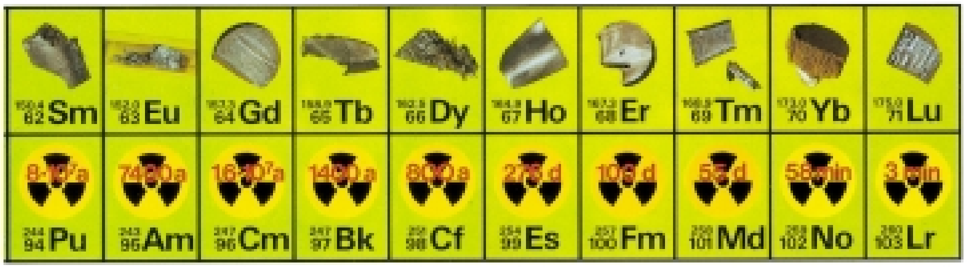


Figure 2.35 Pictorial Periodic Table
The periodic table shown here illustrates samples of the elements and common uses. It differs somewhat from the up-to-date table that you will find in Appendix B.


Atomic Mass
Atomic Number
10.8 5 B
Symbol
Radioactive
10
11
12
13
14
15
16
17
18
4.0 2 He
10.8 5 B
12.0 6 C
14.0 7 N
16.0 8 O
19.0 9 F
20.2 10 Ne
27.0 13 Al
28.1 14 Si
31.0 15 P
32.1 16 S
35.5 17 Cl
39.9 18 Ar
58.7 28 Ni
63.5 29 Cu
65.4 30 Zn
69.7 31 Ga
72.6 32 Ge
74.9 33 As
79.0 34 Se
79.9 35 Br
83.8 36 Kr
106.4 46 Pd
107.9 47 Ag
112.4 48 Cd
114.8 49 In
118.7 50 Sn
121.8 51 Sb
127.6 52 Te
126.9 53 I
131.3 54 Xe
195.1 78 Pt
197.0 79 Au
200.6 80 Hg
204.4 81 Tl
207.2 82 Pb
209.0 83 Bi
103 a
209 84 Po
8.3 h
210 85 At
3.8 d
222 86 Rn


150.4 62 Sm
152.0 63 Eu
157.3 64 Gd
158.9 65 Tb
162.5 66 Dy
164.9 67 Ho
167.3 68 Er
168.9 69 Tm
173.0 70 Yb
175.0 71 Lu
8·10⁷a
244 94 Pu
7400a
243 95 Am
1.6·10⁷a
247 96 Cm
1400 a
247 97 Bk
800 a
251 98 Cf
276 d
254 99 Es
100 d
257 100 Fm
56 d
258 101 Md
58 min
259 102 No
3 min
260 103 Lr

Find Out ACTIVITY

Infer and Identify

How can you tell which element is which? The physical and chemical properties of a substance will give you clues. Can you solve the mysteries? Appendix C may be helpful once you have filled in all of the chart except for the element's name.

Safety Precautions

Identify safety precautions and discuss with your teacher.

Materials

elements and testing apparatus, as identified by your teacher

Procedure

Performing and Recording
Communication and Teamwork

1. Make an observation chart.
2. Select an element. Discuss general observations of the element with your group. Record your observations on the chart.
3. As a group discuss and decide on the chemical and physical properties for which you could safely test the element. Get approval for your tests and safety precautions from your teacher.
4. Conduct the tests. Record your results on your chart. Discuss any new questions, problems, or ideas that arise from the test results. Try to come to a consensus with your group on the identity of the element. Return the element to its proper location.
5. Repeat steps 2–4 for each of the elements.

What Did You Find Out?

Analyzing and Interpreting

1. Which two elements were the easiest to identify? Why?
2. Which properties were the hardest to determine?
3. Some of the elements were metals. Make a hypothesis about what characteristics a substance must have to be considered a metal.
4. Why do you suppose your teacher did not give you a sample of mercury, bromine, or plutonium?

Extension

5. Find photographs in Figure 2.35, the Pictorial Periodic Table of each of the elements you tested. Compare the illustration with the sample you used. What questions do you have about each element? Choose one of your questions and research the answer. Share your answer with the class.

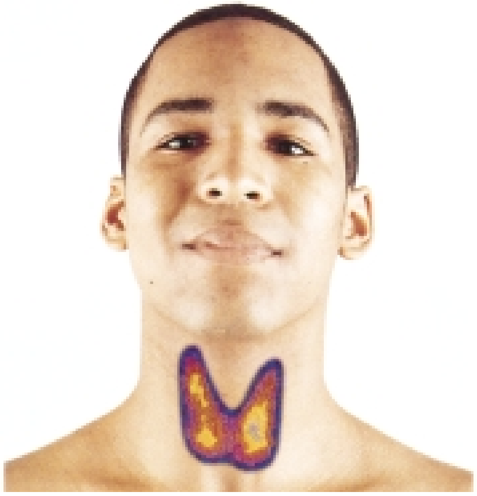


Figure 2.36 A radioactive form of iodine can be used to produce an image of the thyroid gland.

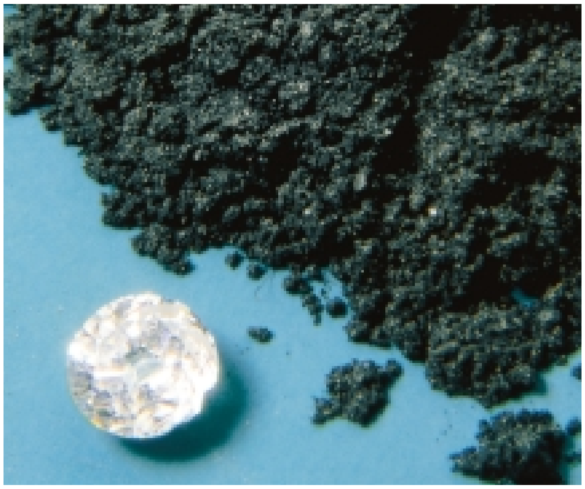


Figure 2.37 Carbon occurs naturally in different forms, such as graphite and diamonds. In which ways are the physical properties of graphite and diamonds different?

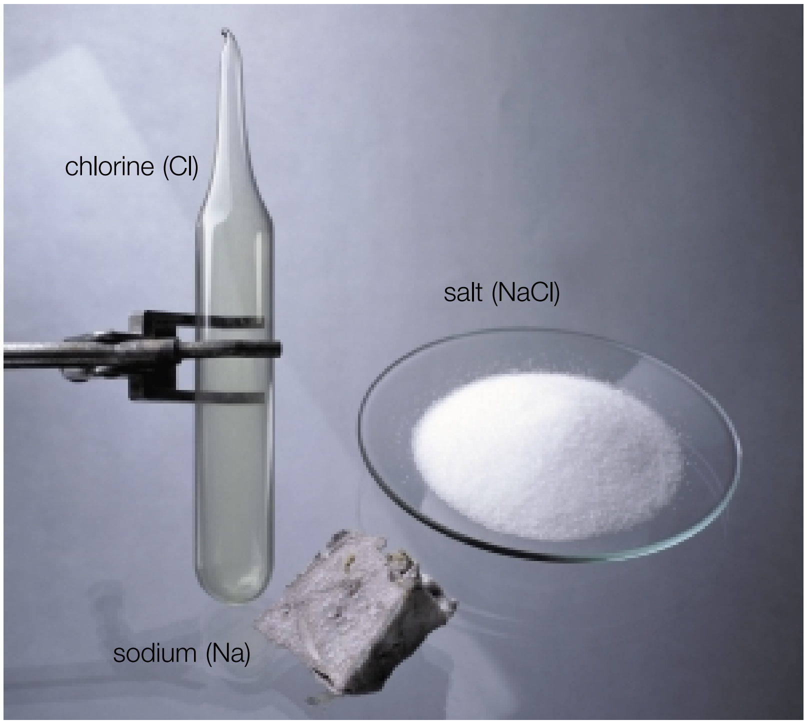


Figure 2.38 Sodium has a silvery lustre, typical of many metals. It is shiniest where it has just been cut. If you have smelled chlorine bleach, then you are familiar with the gas chlorine. Together, sodium and chlorine form salt.

STRETCH Your Mind

Only nine new natural elements were discovered in the twentieth century. However, scientists extended the periodic table by creating synthetic elements in nuclear reactors and particle accelerators. A particle accelerator is a machine used to move nuclear particles at very high speeds. When new elements are created in the accelerator, they last only for a short time — sometimes just a fraction of a second. Why don't they last longer?

TOPIC 5 Review

1. Why is the table called a "periodic" table?
2. How many groups of elements are in the modern periodic table of elements? Why are the elements grouped into rows and columns?
3. List the first 18 elements of the periodic table. State two properties of each element.
4. **Apply** For what purposes might modern scientists use the periodic table?
5. **Thinking Critically** Are the physical properties of the compound sodium chloride (table salt) an average of the properties of the elements it contains? (See Figure 2.38 above.) Explain.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

What would you like to know about elements and their properties? Create a KWL chart about six different elements. List what you know, then list what you wonder about each element. Search for answers at the web site above. Go to the web site above, and click on Web Links to find out where to go next. Then list what you have learned on your chart.

TOPIC 6 Chemical Compounds

There are over 112 elements. These elements can combine in groups of two, three, or more to form compounds. Imagine how many combinations are possible!

What holds elements together when they form compounds? Elements are held together by chemical bonds. Chemical bonds are formed when elements gain, lose, or share electrons. If atoms transfer electrons to other atoms, an **ionic compound** is formed. If atoms share electrons, a **molecular compound** is formed.

In Topic 6 you will learn about what makes molecular and ionic compounds different, and how compounds are named. Some properties of these two types of compounds are summarized in Table 2.4.

Table 2.4 Some Properties of Ionic and Molecular Compounds

Ionic	Molecular
• formed from metallic and non-metallic elements	• usually formed from only non-metallic elements
• forms ions in solution	• does not form ions in solution
• conducts electricity	• usually does not conduct electricity
• solid at room temperature	• solid, liquid, or gas at room temperature

Understanding Formulas for Compounds

At room temperature both hydrogen (H) and oxygen (O) are gases. If hydrogen is burned in oxygen, however, the product is water. You may already know that H_2O represents the formula for water (see Figure 2.39).

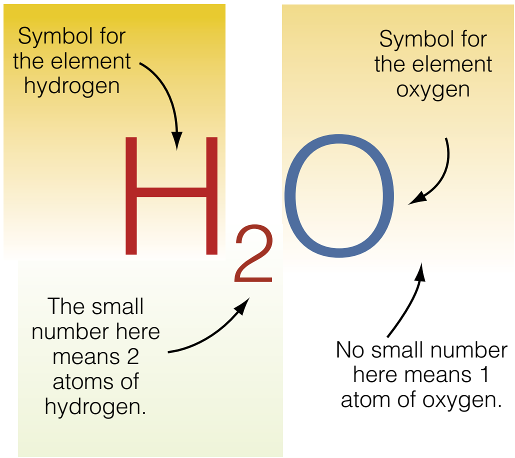

Symbol for the element hydrogen
Symbol for the element oxygen
H_2O
The small number here means 2 atoms of hydrogen.
No small number here means 1 atom of oxygen.

Figure 2.39 Anatomy of a chemical formula

A **chemical formula** uses symbols and numerals to represent the composition of a pure substance. Each symbol in a chemical formula represents an atom of an element. If there is more than one atom of an element, a small number written below the line (a subscript) follows the element's symbol. The subscript shows the number of atoms.

The law of definite composition tells us that every pure substance has a fixed and definite composition. For example, the chemical formula for water represents the composition of pure water wherever it is found. According to the chemical formula H_2O, water must always contain two atoms of hydrogen for each atom of oxygen, whether the water is in a glass or a lake (see Figure 2.40).

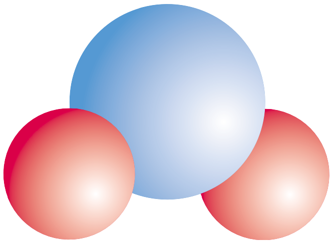


Figure 2.40 Each water molecule contains two hydrogen atoms and one oxygen atom. How does this model of water compare with Dalton's model in Figure 2.17, on page 111?

Molecular Compounds

A **molecule** is the smallest independent unit of a pure substance and is generally a cluster of atoms joined together. These atoms stay linked together regardless of how many times the substance is melted, boiled, or frozen. **Diatomic molecules** are molecules made of two atoms of the same element. Oxygen, nitrogen, and hydrogen are examples of diatomic molecules.

Most molecular compounds do not form large structures. Although the *bonding* between *atoms* is strong, the *attraction* between *molecules* is weak.

When you melt or vaporize a molecular compound, you must supply enough energy to overcome the attraction between the molecules. Because this attraction is weak, most molecular compounds have relatively low melting and boiling points. Because molecular compounds have no free electrons, they are poor electrical conductors, even when in a liquid state.

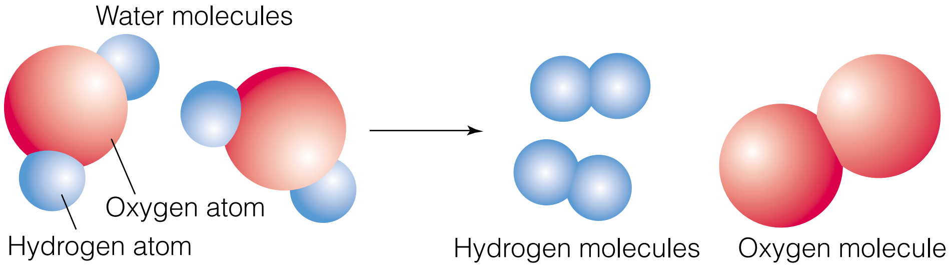


Figure 2.41 During electrolysis the added energy breaks the H_2O molecules apart. Unless there is added energy, the atoms remain fixed or locked in their own independent molecules.

How Are Molecular Compounds Named?

Chemists in all parts of the world work with elements and compounds. They share their knowledge with colleagues in other countries who speak other languages. How is this communication made possible? You already know that elements have universal symbols that are recognized worldwide. Compounds are also named according to global guidelines. The International Union of Pure and Applied Chemistry (IUPAC) is an organization of scientists responsible for setting standards in chemistry. IUPAC committees make recommendations on how compounds should be named.

There are several rules you can learn to help you communicate using the language of chemistry. For example, a compound made from two elements is called a **binary compound**. The names of *molecular* binary compounds follow these rules:

1. Write the entire name of the first element.
2. Change the ending on the name of the second element to *-ide*.
3. Use a prefix to indicate the number of each type of atom in the formula: *mono-* for one, *di-* for two, *tri-* for three, and *tetra-* for four. The prefix *mono-* is used only for the second element.

Suppose you wanted to write the name of the molecular compound, CO_2.

1. First write carbon.
2. Change the name of the second element (oxygen) to end with *-ide* (oxide).
3. There is only one carbon atom, so there is no change. There are two oxygen atoms, so add the prefix *di-*.

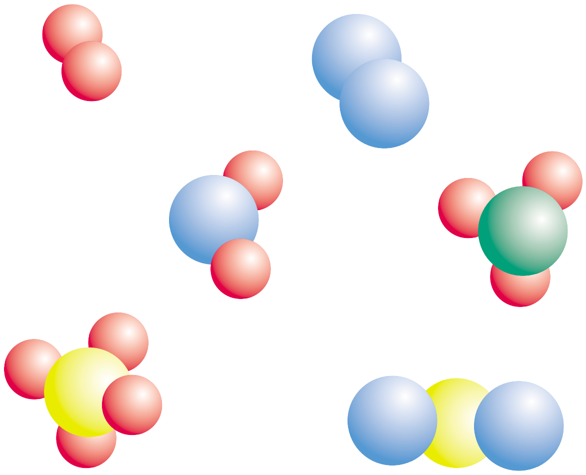


Figure 2.42 Pictured above are some examples of common molecular compounds and diatomic molecules. Red spheres are hydrogen, blue spheres are oxygen, green spheres are nitrogen, and yellow spheres are carbon. Name the compounds and diatomic molecules.

If you are changing from the written name to the symbol:

1. Write the symbols for the elements in the same order as they appear in the name.
2. Use subscripts to indicate the numbers of each type of atom.

Some molecular compounds are known by common names as well as by chemical names. For example, what is the formula for water? Use the formula and the steps above to determine the chemical name for water. Then read Table 2.5, Common Molecular Compounds. Notice the small symbols in parentheses after each compound. These symbols indicate the state of matter: (s) for solid, (l) for liquid, (g) for gas and (aq) for aqueous (a solid dissolved in water).

You can build your own model molecular compounds in the next activity. Then learn more about the formulas for molecular compounds in Think & Link Investigation 2-E: Interpreting Chemical Formulas.

Table 2.5 Common molecular compounds

Name	Formula	Description
Carbon monoxide	$CO_{(g)}$	poisonous gas
Carbon tetrachloride	$CCl_{4(l)}$	organic solvent
Silicon dioxide	$SiO_{2(s)}$	major component of sand and glass
Sulfur dioxide	$SO_{2(g)}$	result of burning sulfur, a component of acid rain

Find Out ACTIVITY

Building Model Molecules

Scientists often build models to help them understand the components of matter. How will a model help you understand molecules?

Procedure

Build your own models of each of the following molecules: hydrogen, water, ammonia, and methane. You will find the chemical formula for each of these substances in Appendix C. You may use the model components provided by your teacher, or you may create your own model kit. Use materials such as coloured mini-marshmallows and toothpicks. A computer drawing program could also be used.

What Did You Find Out?

1. How are molecules of hydrogen and oxygen similar?
2. How are molecules of ammonia and methane similar?

Extend Your Skills

3. Make a model of ethanol.
4. Find examples of molecule models on the Internet. How are they similar to your models?

THINK & LINK

INVESTIGATION 2-E

SKILLCHECK

Initiating and Planning

✸ Performing and Recording

✸ Analyzing and Interpreting

Communication and Teamwork

Interpreting Chemical Formulas

Chemists have described many groups and types of compounds. What do the chemical formulas indicate about molecular compounds?

Part 1

Think About It

Most compounds are made of molecules. Examples include water, carbon dioxide, propane, and glucose (sugar). Interpret the formulas for these compounds by using the example of water in this table as a guide.

The Composition of Four Compounds

Name of compound	Formula of molecule	Elements present	How many atoms of each?
water	H_2O	hydrogen, oxygen	2 atoms H, 1 atom O
carbon dioxide	CO_2		
propane	C_3H_8		
glucose	$C_6H_{12}O_6$		

What to Do

1. Based on the table above, how many atoms, in total, are present in the following molecules?
   - **(a)** one water molecule
   - **(b)** one carbon dioxide molecule
   - **(c)** one propane molecule
   - **(d)** one glucose molecule

Word **CONNECT**

Dalton and others of his time used the terms "compound particles" and "compound atoms" when theorizing about what happens to atoms when elements combine. The Italian physicist Amedeo Avogadro (1776–1856) introduced the term "molecule." What did "molecule" originally mean? Check print or electronic sources to find out.

Part 2

Think About It

Many elements exist as molecules under ordinary conditions. For example, the air you inhale with every breath is mostly a mixture of two compounds and two elements, as shown in the following table.

Some Components of Air

Name of gas	Compound or element?	Made of molecules?	Formula	Number of atoms per molecule
water vapour	compound	yes	H_2O	3
carbon dioxide				
oxygen				
nitrogen				

What to Do

1. The first line in the table is complete. Copy the table and fill in the missing information in the other three lines.

Looking Ahead

Have you had your plan approved by your teacher for your End of Unit Investigation: Tough as Nails? Depending on your design, it may be time to start your investigation in the next few days so it will be finished by the end of the unit.

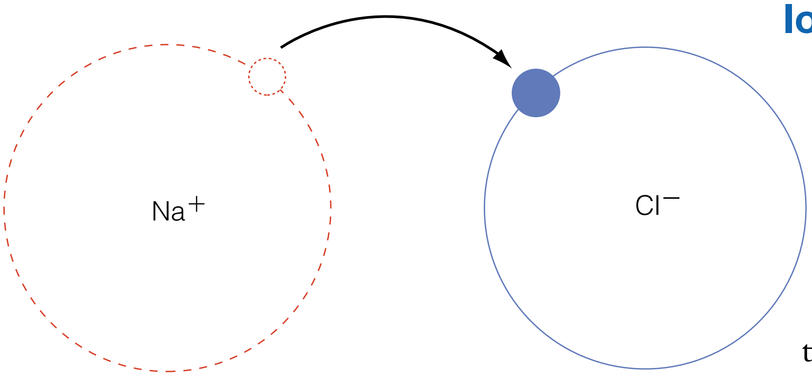


Figure 2.43 One electron has been transferred from sodium to chlorine. Both atoms now have a stable electron arrangement.

Ionic Compounds

When an atom gains or loses electrons, the atom is no longer neutral. It has become an **ion**, which is a particle or group of particles with a positive or negative charge. Atoms are neutral because they contain equal numbers of positive and negative charges. A sodium atom contains 11 protons and 11 electrons. If sodium loses one electron (as shown in Figure 2.43), it has 11 protons but only ten electrons, so the ion is positive.

The electron rearrangement leaves the chlorine atom with a slight negative charge and the sodium atom with a slight positive charge. There is no longer an equal number of electrons and protons in each atom. The sodium will no longer have its original properties, however, and neither will the chlorine. Instead of two elements, the atoms now form a compound — sodium chloride, or NaCl, which is common table salt.

Conductivity is the ability of a substance to carry an electric current. Ionic compounds separate into positive or negative particles (ions) when they dissolve in water. Both negative and positive ions are formed in the water. Charged particles can carry an electric current through the water (see Figure 2.46). How can conductivity be used to determine whether a compound is ionic or molecular?

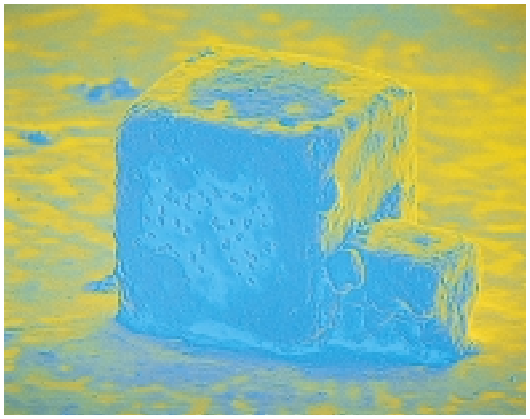


Figure 2.44 Salt is made of positively charged sodium ions and negatively charged chloride ions. The positive and negative ions form a cube-shaped arrangement. This photograph shows the electron microscope view of the tiny crystals.

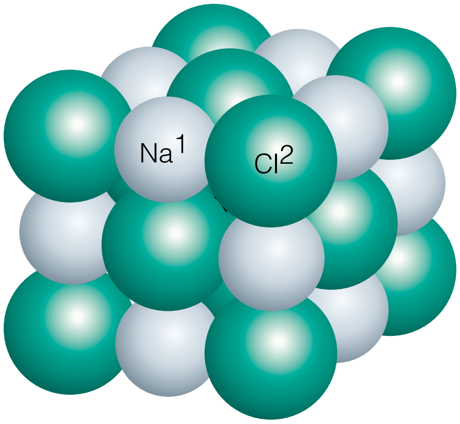


Figure 2.45 Positive sodium ions attract negative chloride ions to form a cube-shaped arrangement in sodium chloride. In this arrangement, six chloride ions surround every sodium ion, and six sodium ions surround every chloride ion. The forces holding each ion in place are ionic bonds.

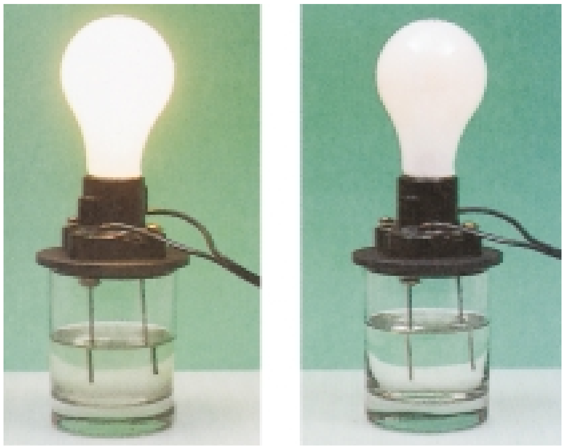


Figure 2.46 A simple conductivity tester can be used to determine if a solution conducts electricity. How do you know the solution conducted the electricity?

How Are Ionic Compounds Named?

The rules for naming binary ionic compounds are similar to those for binary molecular compounds. However, the name of the compound does not indicate the number of ions of each element.

1. The name includes both elements in the compound, with the name of the metallic element first.
2. The non-metallic element is second. Its ending is changed to -*ide*.
3. Subscripts indicate the ratio of ions in the compound. For example, in $CaCl_2$ the ratio of calcium to chloride ions is 1:2.

Name these ionic compounds: NaCl, NaF, LiCl, and ZnS.

Some ionic compounds are known by their common names, such as $CaCO_3$ (limestone) and NaOH (lye). In the next activity, you will work with the formula for a familiar ionic compound.

Find Out ACTIVITY

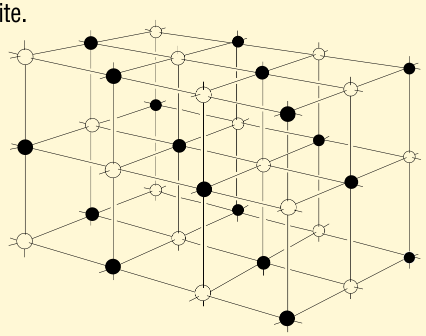
Formulas for Ionic Compounds

Some compounds consist of large collections of ions. For example, sodium chloride (table salt) is made of sodium ions and chloride ions. The following representative model shows part of a salt crystal. It shows the position of the ions in the salt crystal, but it does not show what the crystal actually looks like.

Procedure ✷ **Analyzing and Interpreting**

Examine the model carefully to see how the two elements are arranged.

The symbol for sodium is Na. The sodium ions are black in this model. The symbol for chlorine is Cl. The chloride ions are white.



What Did You Find Out?

1. Count the total number of ions of each element that are represented in the model.
   - **(a)** How many sodium ions are represented?
   - **(b)** How many chloride ions are represented?
2. The formula for sodium chloride is normally written as NaCl. Should the formula for the part of the salt crystal shown here be Na_{18} Cl_{18}? Why or why not?
3. Ionic compounds are made of oppositely charged ions held together strongly in well-organized units. How could you use a pair of magnets to make a model of the attractive forces in ionic compounds?

Extension

4. Try to match each of the following ionic compounds with its common use. Then check your work by using the Internet or library resources.

Compounds: potassium chloride, potassium iodide, sodium fluoride

Uses: A toothpaste additive to strengthen tooth enamel

A salt substitute used by people avoiding sodium for health reasons

A table salt additive to prevent iodine deficiency

INQUIRY

INVESTIGATION 2-F

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- Communication and Teamwork

Comparing Ionic and Molecular Properties

In this investigation, you will examine a number of substances to find out which are ionic and which are molecular. You will then conduct some further tests to compare the properties of ionic and molecular compounds.

Safety Precautions

- If you are using an older model conductivity tester that is not battery operated, be extremely careful to keep the ends well separated while you perform your tests.
- Be careful not to touch hot surfaces.

Question

How do the properties of ionic and molecular substances compare?

Apparatus

conductivity tester
wire gauze
ceramic evaporating dish
8 small beakers (100 mL)
hot plate
scoopula
magnifying lens
stirring rod
ring clamp and stand
8 labels

Materials

400 mL distilled water
sodium iodide, NaI
copper (II) nitrate, $Cu(NO_3)_2$
magnesium chloride, $MgCl_2$
graphite (C)
paraffin wax, $C_{25}H_{52}$
sucrose, $C_{12}H_{22}O_{11}$
starch (chains of CH_2OH)

Substance	Ionic (yes/no)	Solubility in water	Conductivity test	Appearance	Odour	Texture	Relative melting point
sodium iodide							
copper (II) nitrate							
magnesium chloride							
graphite							
paraffin wax							
sucrose							
starch							

Procedure

① Make a table like the one above. Give your table a title.

② **Prediction** Based on information from the periodic table and what you already know, **predict** which substances are ionic. Write yes or no in the Ionic column.

③ **Solubility**
(a) Label each beaker with the name of one of the substances to be tested. Pour about 50 mL distilled water into each beaker.

(b) Use the scoopula to add a small quantity of sodium iodide (about the size of a peanut) to the beaker with the appropriate label. Use a stirring rod to dissolve the solid. Note whether the solid dissolves completely. **Record**. Repeat for each of the other substances.

4 **Conductivity**

(a) Add 50 mL distilled water to a beaker. Label it "Control." Test the "Control" beaker with the conductivity tester. **Record** your results.

(b) Test the solution from step 3 with the conductivity tester. **Record** your results.

5 **Appearance** Examine a small sample of each substance using a magnifying lens. Briefly describe the shape of the grains.

6 **Odour** Carefully smell each compound. In your table, describe any odour.

7 **Texture** **CAUTION:** You must wear protective gloves for this test.

(a) Test the texture of each substance by rubbing a small sample between your thumb and forefinger. Use words like "soft," "waxy," "brittle," and "granular" to **record** your observations.

(b) Wash your hands thoroughly when you have completed this step.

8 **Relative Melting Point** Choose one solid that you think is ionic and one solid that you think is molecular.

(a) Place a small sample of each solid into an evaporating dish. Put the samples on opposite sides of the dish.

(b) Heat the evaporating dish evenly with a hot plate until one of the substances melts. In your table, **record** the relative melting point for this substance as "low" and for the other substance as "high."

(c) After the evaporating dish has cooled down, clean it and put it away.

Analyze

1. **(a)** Which compounds used in this investigation are ionic?
   (b) In which part of the periodic table do the elements in ionic compounds occur?

2. **(a)** Which compounds are molecular?
   (b) In which part of the periodic table do their elements occur?

3. **(a)** In general, are ionic compounds soluble in water?
   (b) In general, are molecular compounds soluble in water?
   (c) Did you find any compounds that were exceptions to your answers for parts (a) and (b)?

Conclude and Apply

4. In general, which type of substance seems to be harder, ionic or molecular?

5. Share your results on relative melting points with other groups in your class.
   (a) Which type of compound seems to have the higher melting point?
   (b) What might explain the differences in data among groups?

6. Summarize some general properties of ionic and molecular compounds. Explain how the evidence you gathered supports your summary.

Find Out ACTIVITY

Multimedia Models

You have been learning about atomic structure, elements, and compounds. Now it's your turn to be the teacher. How much information can you pack into 5 min of presentation time?

Procedure ✴ Performing and Recording

1. Work with a partner or in a small group. Select (or be assigned) a classification system for your presentation, such as a the periodic table; a comparison of atomic theories; metals and non-metals; or ionic and molecular compounds.
2. Your presentation can only last 5 min. Decide what information you want to include in the presentation and which formats to use. Be sure to describe the work of scientists. Part of your presentation will include a model that you have made of your subject. The model could be made of clay or other materials, or it could be made with computer software. Consider using tape recorders, video cameras, songs, dances, skits, posters, and so on as part of your presentation. Have your teacher approve your choice of formats.
3. Prepare and practise the presentation with your group. Ask for feedback from classmates, parents, or friends.
4. Make your presentation. Enjoy!

What Did You Find Out? ✴ Analyzing and Interpreting

1. In what ways is your model an accurate portrayal of your subject? In what ways is it different from your actual subject?
2. How did having a model help your audience in understanding what you were presenting?
3. If you had unlimited access to tools and equipment, how would you design your model to be more accurate?
4. How could you improve your ability to work with a group?

DidYouKnow?

Carbon is one of the most plentiful and important elements on Earth. It is found in foods, plastics, plants, and animals. Carbon atoms can form small groups with other atoms, such as hydrogen. These groups can string together like beads to form chain-like molecules.

TOPIC 6 Review

1. Name four properties of molecular compounds.
2. Name four properties of ionic compounds.
3. In terms of electrons, what is the difference between a molecular compound and an ionic compound?
4. Define molecule. Define diatomic molecule.
5. What is an ion?
6. Write the names of these compounds. Is each compound molecular or ionic?
   LiCl ZnS SO_2 CO HCl NaF
7. The formula for hydrogen peroxide is H_2O_2. Which elements are present in hydrogen peroxide? How many atoms are in each molecule?
8. **Thinking Critically** When salt (sodium chloride) dissolves in water, the salt particles break apart and form positive sodium and negative chlorine ions. If the salt particles break apart, why does the water still taste salty?

Wrap-up TOPICS 4-6

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

element symbols
chemical family
atomic mass
atomic number
mass number
ionic compound
molecular compound
chemical formula
molecule
diatomic molecules
binary compounds
conductivity

Reviewing Key Terms

1. Write the words from column A in your notebook. Select the terms from column B that match column A words. (4–6)

A

- halogen
- alkali metal
- atomic number
- noble gas
- alkaline earth metal
- diatomic molecule

B

- hydrogen
- gold
- argon
- sodium
- number of neutrons
- number of protons
- beryllium
- chlorine

Understanding Key Concepts

2. Name three examples of highly corrosive elements. (4)
3. Name three highly reactive metals. (4)
4. Explain why some elements must be stored in oil. Give an example (4).
5. State two differences and two similarities between the noble gases and the alkali metals. (4)
6. State the element symbol, atomic number, and atomic mass of lithium, beryllium, phosphorus, and sulfur. (4–5)
7. The ______________ table is a collection of elements. Vertical columns in the table are called ______________ . Horizontal rows in the table are called _____________. (5)
8. State whether each compound is ionic or molecular: hydrogen peroxide, carbon tetrachloride, aluminum oxide, and nitrogen dioxide. (6)
9. For which organization is IUPAC the abbreviation? (6)
10. Why can ionic compounds conduct electricity, but molecular compounds usually can not? (6)

TOPIC 7 Chemical Reactions

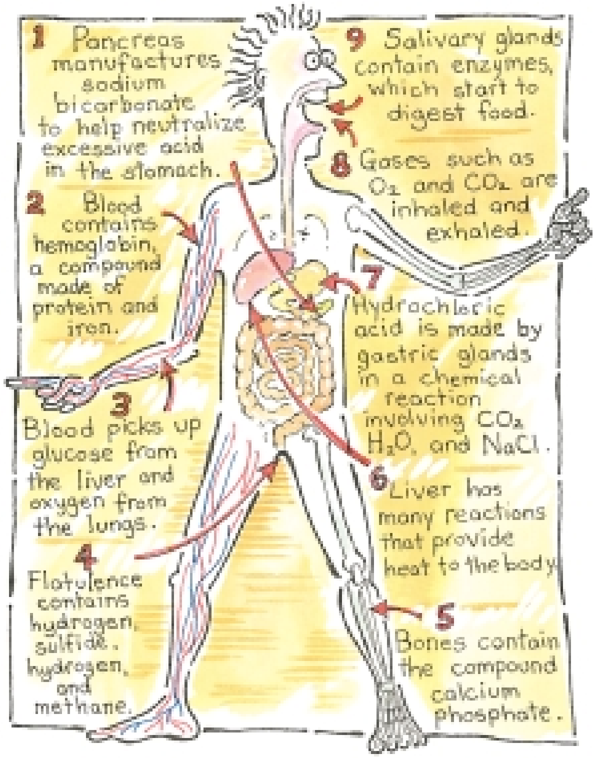

1 Pancreas manufactures sodium bicarbonate to help neutralize excessive acid in the stomach.
2 Blood contains hemoglobin, a compound made of protein and iron.
3 Blood picks up glucose from the liver and oxygen from the lungs.
4 Flatulence contains hydrogen sulfide, hydrogen, and methane.
5 Bones contain the compound calcium phosphate.
6 Liver has many reactions that provide heat to the body.
7 Hydrochloric acid is made by gastric glands in a chemical reaction involving CO_2, H_2O, and NaCl.
8 Gases such as O_2 and CO_2 are inhaled and exhaled.
9 Salivary glands contain enzymes, which start to digest food.

Figure 2.47 Some chemical reactions in the body

You can smell brownies baking in the oven and smoke from a campfire. You can see gas bubbles produced when you combine vinegar and baking soda. These are signs of chemical changes. Some chemical changes are easy to detect. Other chemical changes are less obvious.

In a **chemical reaction**, two or more substances undergo a reorganization of atoms to form other substances. The substances that go into a chemical reaction are the **reactants**. The substances produced by a chemical reaction are the **products**. The properties of the products are different from those of the reactants. Changes in properties that might occur in a chemical reaction are shown in Figure 2.48 (on this page and the next page).

Not all changes in colour, temperature, and odour indicate chemical reactions. Boiling water creates a gas, but no chemical change has happened — water has only changed state from liquid to gas. A change in state is a physical change. How do you decide whether a chemical reaction has occurred? Find out in the next activity.

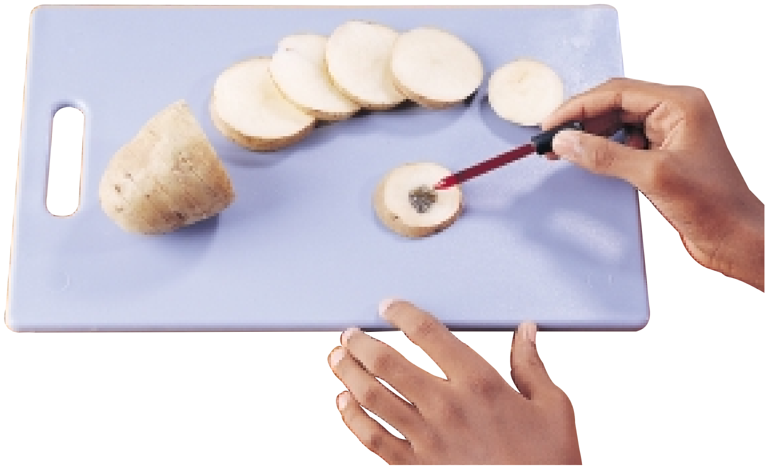


Figure 2.48A When iodine solution is placed on a raw potato, the iodine reacts with the starch to produce a blue-black colour. *Colour change* can indicate a chemical reaction.

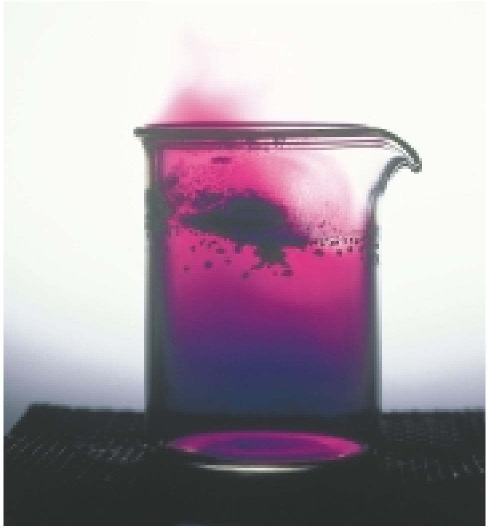


Figure 2.48B A precipitate is a suspension of small solid particles in a liquid. Sometimes a *precipitate* and/or *gas* is produced or dissolved in a chemical reaction.

Figure 2.48C *Heat* and *light* can be absorbed or produced during a chemical reaction. When charcoal briquettes are burned, heat and light are produced.

Figure 2.48D When food spoils, its odour may change. *Odour changes* can indicate a chemical reaction has taken place.

Find Out ACTIVITY

Is It a Chemical Reaction?

Several reactions have been set up in the science room. Which substances are undergoing chemical reactions? Search for the evidence.

Safety Precautions

Procedure ✷ **Performing and Recording**

1. Make an observation chart to collect your data.
2. Visit one of the stations. Carefully follow the instructions and safety precautions you find there. Record your observations on your chart.
3. Decide if a chemical reaction is taking place. If so, list the reactants.
4. Repeat steps 2 and 3 at each of the stations.

What Did You Find Out? ✷ **Analyzing and Interpreting**

1. Which stations had chemical reactions? What evidence made you think that a chemical change had occurred?
2. Which stations had physical reactions? What evidence made you think that a physical change had occurred?
3. When two or more substances are chemically combined, new substances are formed. Infer which new substances might have been formed at each of the stations with chemical reactions.
4. List three examples of chemical reactions in your everyday life. What evidence tells you that each is a chemical reaction?

Chemical Equations

How do chemists describe chemical reactions? For example, how might the reaction of silver and bromine Figure 2.49 be described?

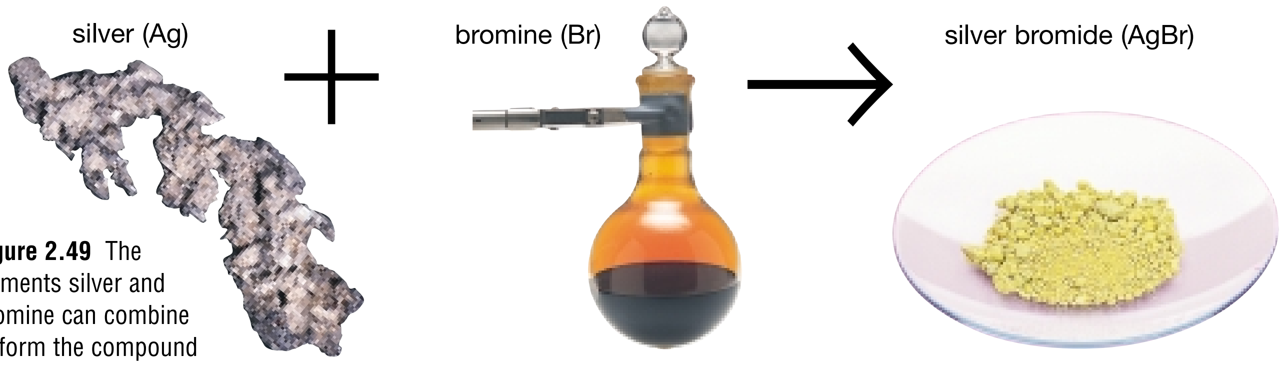


Figure 2.49 The elements silver and bromine can combine to form the compound silver bromide.

STRETCH Your Mind

Notice the number 2 before Mg in the equation. This number is called a coefficient and is used to "balance" the equation. Count the number of Mg atoms on each side. Are they the same? Are the oxygen atoms balanced?

The equation Ag + Br → AgBr is unbalanced, since bromine is a diatomic molecule and should be written as Br_2. How would you balance the equation?

One way to describe a chemical reaction is with a word equation that describes the reactants and products. The arrow means "produces."

silver + bromine → silver bromide

You can convert a word equation into a chemical equation by substituting the chemical formulas for the chemical names:

$$Ag + Br \rightarrow AgBr$$

(silver) (bromine) (silver bromide)

You learned in Topic 6 that chemists usually put symbols in parentheses behind the reactants and products to indicate the states of matter. For example, magnesium, a solid, is used to create bright light in fireworks and flash bulbs. The magnesium oxide formed is soft, grey in colour and easily crumbles into dust. The word equation for the reaction is

magnesium + oxygen → magnesium oxide

The chemical equation for the reaction of magnesium in oxygen is

$$2\ Mg_{(s)} + O_{2(g)} \rightarrow 2\ MgO_{(s)} + \text{light}$$

When you studied the law of conservation of mass, you learned that atoms are neither lost nor created in a chemical reaction. The atoms just change partners as old substances are changed into new substances. For example, you have probably observed that when you mix vinegar and baking soda, a vigorous chemical reaction occurs (see Figure 2.50). The chemical equation may look complicated, but you now know how to understand each part:

$$HC_2H_3O_{2(aq)} + NaHCO_{3(s)} \rightarrow NaC_2H_3O_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

(vinegar) (baking soda) (sodium acetate) (water) (carbon dioxide)

Figure 2.50 When vinegar is poured on baking soda (sodium hydrogen carbonate), bubbles of carbon dioxide gas form quickly. Water and sodium acetate are also formed.

What states of matter were the reactants in? What states of matter are the products in? Notice how the atoms have changed partners in the reaction as new substances were created.

Breaking Chemical Bonds

Chemical bonds are forces that cause a group of atoms to behave as a unit. Energy is stored in chemical bonds. To break bonds, energy must be added. When bonds form, energy is released.

All chemical reactions involve changes in energy. Energy is either produced or absorbed during a chemical reaction. For example, the burning of wood is a chemical reaction (see Figure 2.51). Cellulose and other substances in the wood combine with the oxygen from the air and produce carbon dioxide and water. Energy, light, and heat are also produced in this reaction. Chemical reactions that give off heat are called **exothermic** reactions. When methane in natural gas is burned in a furnace, energy in the form of heat is created as shown by the equation below:

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)} + \text{energy (heat)}$$

methane + oxygen → carbon dioxide + water + energy (heat)

What are the reactants in this equation? What are the products?

Figure 2.51 Compounds in wood chemically combine with oxygen when they burn to form water and carbon dioxide.

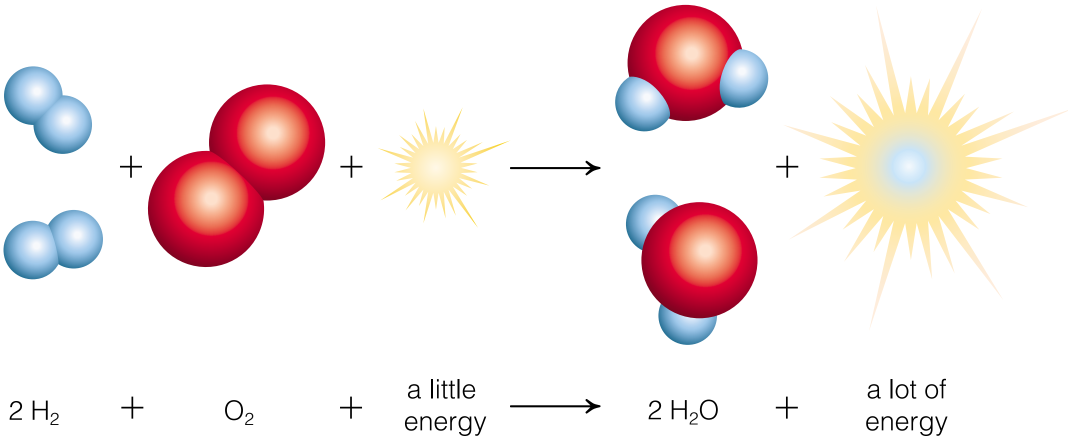


Figure 2.52 It takes only a small amount of energy to start the reaction between hydrogen and oxygen to form water. The energy released by the reaction is much greater, so the reaction is exothermic.

Off the Wall

Nitroglycerine is used not only in explosives, it is also used as medicine for heart disease. Tiny amounts of nitroglycerin taken in pills dilate constricted blood vessels.

Figure 2.53 An explosion is an exothermic reaction. During the reaction of nitroglycerin with the air, so much energy is released that an explosion occurs. Can you name the four gases produced by an explosion of nitroglycerin?

$$4C_3H_5N_3O_{9(l)} \rightarrow 6N_{2(g)} + 12CO_{2(g)} + 10H_2O_{(g)} + O_{2(g)}$$

Sometimes energy is absorbed during a chemical change. Chemical reactions that absorb energy are called **endothermic** reactions. Earlier you learned that electricity was necessary to decompose water into oxygen and hydrogen. The reaction does not occur unless energy in the form of an electric current is passed through the water. The absorbed energy is used to change the state of matter and change the forces holding the water together.

Chemical changes occur in all foods when they are cooked. For example, when baking soda ($NaHCO_3$) is mixed into some kinds of cookie dough, and the dough is baked in a hot oven, a chemical reaction occurs. The baking soda absorbs energy and breaks down into carbon dioxide, water, and sodium carbonate (Na_2CO_3). The CO_2 gas and gaseous H_2O (steam) puff up the cookies. Figure 2.55 shows another endothermic reaction.

Pause& Reflect

Do you recognize the following equation? The series of chemical reactions shown below takes place in the presence of chlorophyll.

$$6CO_{2(g)} + 6H_2O_{(l)} \xrightarrow{\text{light}} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$$

The equation represents the process of photosynthesis. Is photosynthesis an endothermic or exothermic reaction? Why?

When you eat sugars and starches, you are eating molecules formed by endothermic reactions. Your cells break down these molecules in an exothermic process that supplies your body with energy. The exothermic process is called respiration. How is respiration related to photosynthesis? What do you think is the chemical equation for respiration?

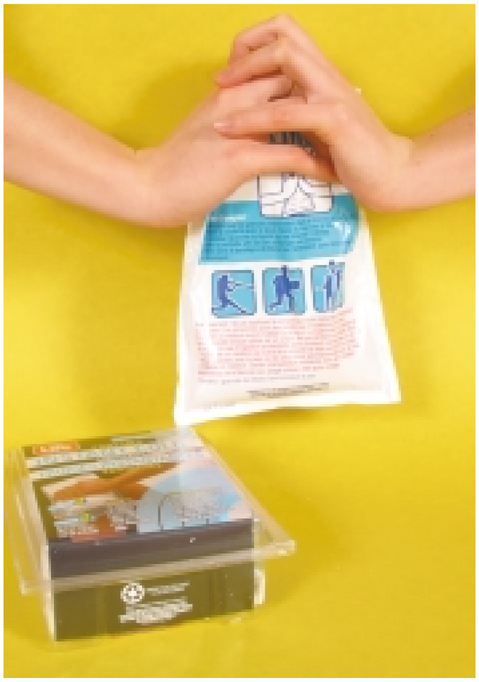
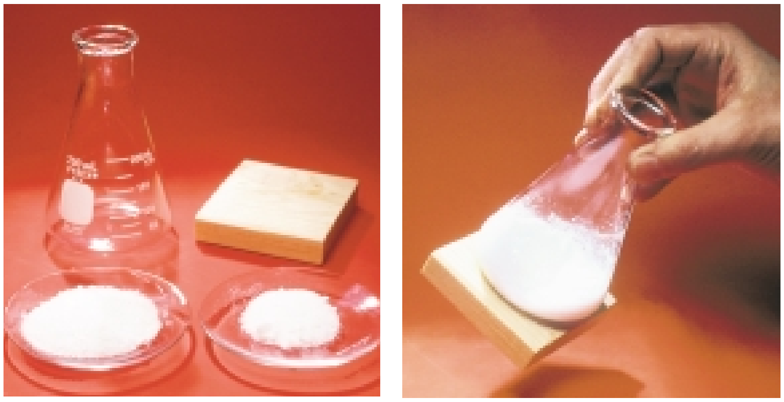


Figure 2.54 Both hot and cold packs are available for treating sports injuries. Sometimes, the temperature change is produced by a solute dissolving in water. Hot packs generally use calcium chloride ($CaCl_2$) and cold packs generally use ammonium nitrate (NH_4NO_3). Which of these chemicals produces an endothermic reaction?



Figures 2.55 When ammonium thiocyanate and barium hydroxide octahydrate are mixed, an endothermic reaction occurs. Heat is absorbed from the surroundings. The Erlenmeyer flask becomes very cold. If water is placed on the bottom of the flask, it will freeze the flask to a wooden block.

Off the Wall

Make-up artists use many chemical reactions to provide special effects on television and in the movies. If an actor is to appear to have skin on his or her arm destroyed by acid, the make-up artist places a thin layer of baking soda in the make-up. When the acid (a mild solution of vinegar) is sprayed, a chemical reaction takes place. The actor's skin appears to melt away. The foaming skin is really carbon dioxide gas and make-up rolling off the actor's arm.

DESIGN YOUR OWN

INVESTIGATION 2-G

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Hot Potato, Cold Potato

Hydrogen peroxide (H_2O_2) combines readily with substances that contain oxygen. Liver and potato both have oxygen in them. Design an investigation to determine the type of reaction that happens when hydrogen peroxide combines with liver and potatoes.

Question

When hydrogen peroxide is combined with liver or potato slices, are the reactions endothermic or exothermic?

Safety Precautions

- Hydrogen peroxide can irritate your eyes and skin.
- Be sure to wear protective equipment.
- If you accidentally spill hydrogen peroxide on your skin, wash it off with lots of cool water.

Apparatus

thermometer
other apparatus, as approved by your teacher

Materials

3% hydrogen peroxide
potato and beef liver slices of varying masses

Skill FOCUS

To find out more about how to design your own investigation, turn to Skill Focus 6.

Procedure

1. Brainstorm with your partners about how you might test whether each reaction is endothermic or exothermic.
2. As a group, make a prediction about each reaction. Give a reason why your prediction might be correct.
3. Decide what your manipulated variable will be. What will be your control variables? How much hydrogen peroxide will you add to each sample? How will you measure temperature change?
4. Create a data table for collecting your data.
5. Have your teacher approve your investigation method, data table, and safety precautions.
6. Conduct your investigation. Remember to regulate the controlled variables.
7. Repeat your investigation several times to collect more data.

Analyze

1. **(a)** What was your manipulated variable?
   (b) What was the responding variable?
2. Is the reaction between a potato and hydrogen peroxide endothermic or exothermic? How do you know?
3. Is the reaction between liver and hydrogen peroxide endothermic or exothermic? How do you know?
4. Were your predictions correct? Explain why or why not.

Conclude and Apply

5. What is the source of the energy for each reaction?
6. Graph your data. Extend your graph to include predictions for the reaction if you had used a stronger solution of hydrogen peroxide and larger pieces of potato or liver.
7. Evaluate the tools, techniques, and processes you used to gather evidence. What improvements could you make?

Find Out ACTIVITY

Exothermic or Endothermic?

Examine the dissolution of several common solids in water. Is energy produced or absorbed when each solid is dissolved?

Materials

5 test tubes
test tube rack
test tube brush
thermometer
stirring rod
water
various solids provided by your teacher
electronic balance or metric measuring spoons

Procedure ✷ Performing and Recording

1. Measure 15 mL water into a test tube. Set a thermometer in the water. Allow it to come to the water's temperature. Record the temperature. Remove the thermometer from the water.

2. Add 5 g of one of the solids to the water. Stir with a stirring rod until dissolved. Put the thermometer into the solution. Record the temperature.

3. Dispose of the solution as directed by your teacher.

4. Repeat steps 1–3 for each of the solids to be tested.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Which of the solids dissolved exothermically? Which dissolved endothermically?

2. Compare your results with those of other groups. How can you explain any differences in data?

3. Calculate the average of all groups' data for each substance. Display the averages as a graph.

Extension

4. Suppose you were designing a cold pack that could be used by medical personnel. Which of the solids you tested could be mixed with water in the pack? Why?

Pause& Reflect

Hydrogen peroxide is often used to bleach colour out of hair. If you were to have your hair bleached blonde, would your head feel cold or hot as the hydrogen peroxide was applied? Why?

TOPIC 7 Review

1. Describe six types of evidence that might indicate a chemical reaction has occurred.

2. Give two examples of a chemical equation using words. Restate the equations using chemical formulas.

3. What is the difference between an endothermic and an exothermic reaction? Give two examples of each.

4. On which side of the arrow in an equation are the products usually found? On which side are the reactants usually found?

TOPIC 8 Reaction Rate

Chemical reactions can occur at different speeds (See Figures 2.58 A, B, and C). Why does one reaction take longer than another? Can you measure the speed of a chemical reaction? Can you slow down or speed up a chemical reaction?

The **reaction rate** is a measure of how fast a reaction occurs. To find the rate of reaction, you can measure either how quickly one of the reactants is disappearing or how quickly one of the products is appearing. Both measurements show how the amount of a substance changes per unit of time.

The rate of a chemical reaction can be speeded up or slowed down by changing the temperature. At higher temperatures the rate of most chemical reactions increases. Faster-moving molecules and atoms collide more frequently and therefore can form new substances more quickly. For example, the high temperature inside an oven speeds up the chemical reactions that change the liquid batter into a cake. Fresh fruit and vegetables are often kept in the refrigerator to slow down the chemical reactions.

Other ways of changing the rate of reactions include stirring and changing the size or the concentration of the reactants. Stirring a cake batter will speed up the reaction rate. If you grind up a chemical before mixing it, there will be more surface area for the chemical reaction. If you increase the concentration of a substance, you will increase the number of particles of a substance per unit of volume.

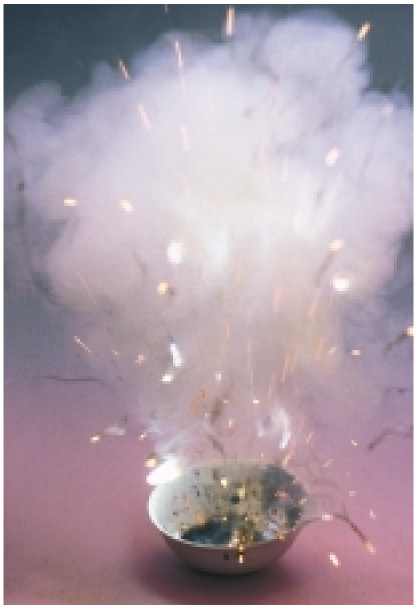


Figure 2.58A To speed up this reaction, ammonium nitrate has been ground into a powder and heated to a high temperature.

Figure 2.58B How could you speed up the reaction rate for a banana to ripen? How could you slow down the reaction rate?

Figure 2.58C How long do you think it has taken for carbonic acid to dissolve limestone and form this cave?

Find Out **ACTIVITY**

Changing with the Times

How can you speed up or slow down a chemical reaction?

Procedure

Do not perform the reactions shown in the table. Read the description of each trial. Think about the effect of the change in conditions on the rate of each reaction.

Chemical reaction	Trial 1	Trial 2
A. Calcite reacts with hydrochloric acid	The calcite is in large pieces	The calcite is in small pieces
B. Sulfuric acid reacts with the lead in a car battery	The acid is a 5% solution	The acid is a 10% solution
C. $NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$	The reactants are stirred	The reactants are not stirred
D. An iron nail reacts with a solution of copper (II) sulfate	The reaction takes place at 65°C	The reaction takes place at 25°C

1. Predict which reactions would be faster in the second trial. Explain.
2. Predict which reactions would be slower in the second trial. Explain.
3. Write a word equation describing the chemical reaction in C.

What Did You Find Out? Analyzing and Interpreting

1. What additional changes could be made in chemical reaction A if you wanted to increase the speed of the reaction?
2. What could be done to slow down the chemical reaction in reaction B?

Extensions

4. What are two advantages to increasing the reaction rate for reactions? Give an example for each.
5. What are two advantages to decreasing the reaction rate for reactions? Give an example for each.

Career CONNECT

The Right Mix

Years ago, pharmacists ground up and mixed together the ingredients of many prescriptions themselves. Even though prescriptions these days come ready-mixed from pharmaceutical companies, pharmacists like Ginette Goulet still need to know about reaction rates.

Ginette has to know which combinations of prescription drugs and other factors can affect chemical reactions and cause problems for the patient. She lets her customers know, for example, if the prescription they receive should not be taken with milk, or if it should be taken on an empty stomach to be most effective. She also lets them know if certain "over-the-counter" drugs, such as antihistamines, should not be taken until they have finished the course of their prescription. Since some customers may be on more than one prescription at the same time, she needs to know which drugs can be taken safely together, so that there are no conflicts between the prescribed drugs.

Speeding Up a Reaction with Catalysts

Another way to change the rate of a reaction is to add or remove a substance called a catalyst. A **catalyst** is a substance that speeds up the rate of a reaction without being changed itself. A catalyst does not affect the amount of product produced in a chemical reaction. A catalyst increases only the *speed* of the reaction.

An **enzyme** is a natural catalyst made by living things. Almost all chemical reactions that take place in the body are catalyzed by enzymes. When you chew a piece of bread, glands in your mouth produce saliva, which contains an enzyme (see Figure 2.57). The enzyme in saliva acts as a catalyst to help break down starches into smaller molecules. When you get a foreign particle in your eye, an enzyme in your tears attacks the cell walls of bacteria, preventing them from infecting the eye.

Many other chemical reactions depend on catalysts to help them work faster. For example, the production of vegetable shortening, synthetic rubber, and high-octane gasoline are all chemical processes that succeed with the help of catalysts. Some laundry detergents contain enzymes that break down the proteins responsible for many stains in clothing.

You will examine the effects of a catalyst in the next investigation.

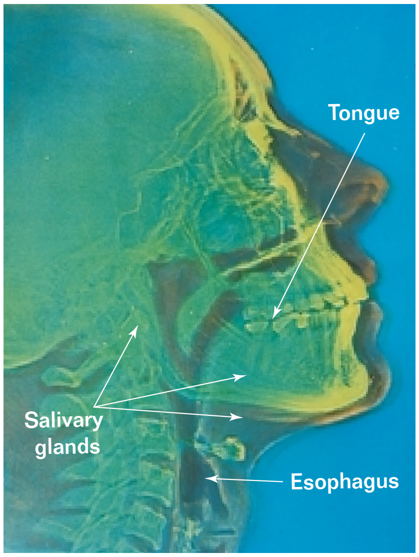


Figure 2.57 As you chew your food, the salivary glands in your mouth release an enzyme. The enzyme speeds up the breakdown of food.

Math CONNECT

A chemical reaction is proceeding at a rate of 4 g of product produced every 30 s. How many minutes will it take to obtain 80 g of the product from the reaction?

Slowing Down a Reaction with Inhibitors

Suppose you wanted to slow down the rate of a chemical reaction. What could you do? You could add an inhibitor. **Inhibitors** are substances that slow down chemical reactions. For example, some plants have natural inhibitors in their seeds to prevent germination until conditions are just right. Inhibitors are added to some foods and medicines to slow down their decomposition.

In the last investigation you observed that hydrogen peroxide decomposes to form oxygen and water (see Figure 2.58). An inhibitor is added to bottles of hydrogen peroxide to prevent its molecules from decomposing too quickly.

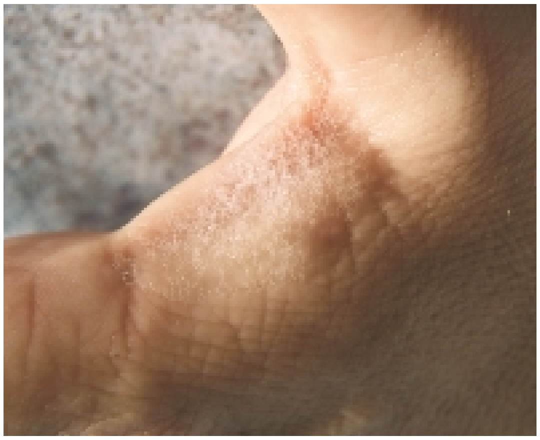


Figure 2.58 Hydrogen peroxide helps to disinfect wounds. Which gas is being produced in this picture?

DidYouKnow?

One of the most important groups of enzymes are the proteases. The proteases break down proteins. Proteases are used in many common products, such as meat tenderizers and contact lens cleaning solution. Proteins secreted by the cells around the eyes build up on contact lenses. Proteases in the cleaning solution help to remove the proteins. Sometimes people have deficiencies in certain enzymes. Research "lactose intolerance" on the Internet or at the library. Find out which enzyme is missing in people who have this condition.

INQUIRY

INVESTIGATION 2-H

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- Communication and Teamwork

Reaction Time

The compound hydrogen peroxide will slowly decompose into water and oxygen if left in an open container.

$$2H_2O_{2(aq)} \longrightarrow 2H_2O_{(l)} + O_{2(g)}$$

Question

What will happen to the decomposition time of hydrogen peroxide if a catalyst is added?

Hypothesis

Formulate a hypothesis about how the addition of a catalyst affects the decomposition of hydrogen peroxide.

Safety Precautions

- Hydrogen peroxide can irritate your eyes and skin. Be sure to wear protective equipment. Do not use more than 5 mL of 3% hydrogen peroxide in each test tube.
- If you accidentally spill hydrogen peroxide on your skin, wash it off with lots of cool water.
- Use caution with hot objects.
- Before striking matches, check that there are no flammable solvents nearby.

Apparatus

600 mL beaker
hot plate
2 test tubes
graduated cylinder (10 mL)
test tube rack
test tube tongs
metric measuring spoons

Materials

water
3% hydrogen peroxide
manganese dioxide
wooden splints
matches

Procedure

1. Make an observation chart like the one below.
2. Add 300 mL water to the beaker. Place the beaker on a hot plate. Turn the hot plate to medium power.
3. Put two test tubes in the test tube rack. Label the test tubes A and B.
4. Pour 5 mL 3% hydrogen peroxide into each of two test tubes.
5. Place 2 mL manganese dioxide in test tube A. **Record** your observations.
6. Light a wooden splint. Blow out the flame and quickly insert the glowing splint into each test tube. Do not let the splint touch the liquid. **Record** your observations.

7. Place both test tubes in the hot water bath. Heat the test tubes until all of the liquid in both test tubes has evaporated.
8. Remove the test tubes from the hot water bath. **Record** your observations.
9. Repeat step 6.
10. Turn off the hot plate. Return all equipment to the proper location. Wash your hands.

	Observations	
Test tube	**Before heating**	**After heating**
A		
B		

Analyze

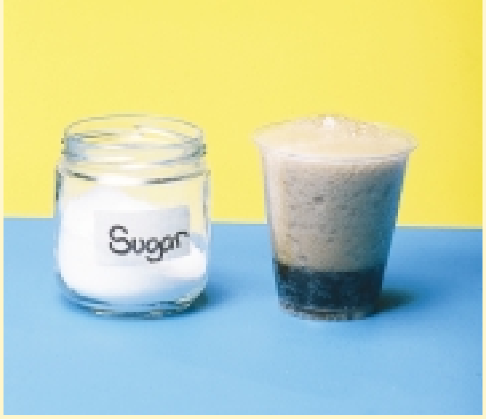
1. Describe what happened when the manganese dioxide was added to test tube A.
2. What gas was produced in the test tube with manganese dioxide? How do you know?
3. In which test tube did the reaction occur more quickly? How do you know?
4. What remained in the test tubes at the end of the procedures?

Conclude and Apply

5. What is the function of the manganese dioxide? Give reasons for your answer.
6. How could you make this experiment more quantitative and make more accurate measurements?

Extensions

7. In the photograph below, sugar has been added to a carbonated beverage. Explain what has happened.



8. Construct a model that shows the decomposition of $2H_2O_{2(aq)}$ into $2H_2O_{(l)}$ and $O_{2(g)}$.

Pause& Reflect

Electronic equipment is usually packaged with small packets of silica gel. Silica gel is a desiccant. Desiccants absorb water vapour from the air. What chemical reaction is silica gel helping to prevent? What else will a dryer environment help prevent? Which other products are packaged with silica gel?

Corrosion

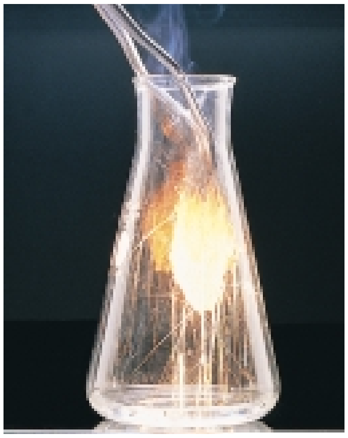


Figure 2.59 Iron combines with pure oxygen in the flask to form iron oxide. This is the same reaction as the rusting of iron, but happens much faster.

What happens to some metals when they are exposed to air and moisture? The metals undergo a chemical reaction and gradually corrode. **Corrosion** is the oxidation of metals or rocks in the presence of air and moisture. You may be familiar with one type of corrosion: **rust**. Rust is iron oxide, a product of the chemical reaction of iron, oxygen, and moisture. One equation for corrosion is shown below:

$$\underset{\text{(iron)}}{4Fe_{(s)}} + \underset{\text{(oxygen)}}{3O_{2(g)}} \rightarrow \underset{\text{(iron oxide)}}{2Fe_2O_{3(s)}}$$

Take a closer look at corrosion in the next activity.

Find Out **ACTIVITY**

Corrosion Collection

What role does a gas play in the process of corrosion?

Materials

gas collecting bottles
steel wool
vinegar
pie plate or dish
grease pencils or tape
water

Procedure

Performing and Recording

1. Clean the steel wool by dipping it in the vinegar.
2. Pack the steel wool tightly in the bottom of the gas collecting bottle so it will not fall out when the bottle is inverted.
3. Fill the pie plate or dish two thirds full with water. Invert the gas collecting bottle containing the steel wool in the pie plate.
4. Mark the starting level of water in the gas collecting bottle with masking tape or a grease pencil.
5. Observe for at least two weeks. Every five days mark the level of water in the gas collecting bottle and add more water to the pie plate.

What Did You Find Out?

Analyzing and Interpreting

1. What happened to the level of water in the gas collecting bottle when you first inverted it in the pie plate? Over a period of two weeks?
2. Why did you invert the bottle in the water?
3. Did a chemical or physical reaction take place? How do you know?
4. List the products and reactants of this reaction.
5. What gas is needed for corrosion to take place? What part of your experiment helped you make this inference?

Extensions

6. How could you have increased the reaction rate? How could you have decreased the reaction rate?
7. Make an inference as to how much of the atmosphere is composed of oxygen. Use the results of your experiment to make this inference.

Preventing Corrosion

Corroded materials lose their strength. Once the top layer of metal has corroded, more surface area is exposed. Oxygen from the air can then reach the inner layers. Corrosion also occurs at points of strain in the metal. Rust will eventually make its way through the metal, and the object will be completely corroded.

One way to protect a metal from corrosion is to apply a thin coating of paint. Another way to protect a metal is to coat it with zinc, which is more resistant to corrosion. The process of coating metals with a thin layer of zinc is called **galvanization**. What are some examples of galvanized products? Houses and buildings under construction are exposed to moisture and air, which could corrode the metal parts before the building is complete. If the nails and other metal parts are galvanized, then corrosion is not a serious problem.

Other metals can also be used as a covering to prevent rust. Some car bumpers are coated with a thin layer of chromium to protect the iron from corroding. The process of covering a metal with another metal by using electrolysis is called electroplating. Chromium is often electroplated onto a softer metal to improve its hardness, stability, and appearance.

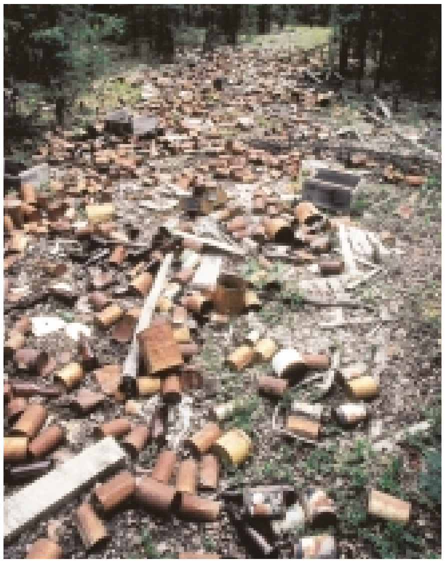


Figure 2.60 The surface of a can that contains iron corrodes quickly outdoors. The rust formed on the surface of the can flakes off easily, so the can continues to corrode. The surface of an aluminum can oxidizes very quickly. The aluminum oxide formed makes a tough protective layer, which does not flake off easily. Therefore, aluminum cans will take over 400 years to degrade. How can you tell that most of the cans in this picture contain iron?

Combustion

Combustion is the highly exothermic combination of a substance with oxygen. Combustion requires heat, oxygen, and fuel. You may be familiar with the burning that takes place in a fireplace, a gas barbecue, or the furnace in your home. Did you know that combustion also takes place inside the internal combustion engine in a car? Gasoline combines with oxygen to release energy to make the car move. Every time something burns, it combines with oxygen from the air. Even the food you eat is converted to energy by combining with the oxygen that you breathe. You will investigate reactants and products of combustion in the next investigation.

Figure 2.61 How is enough heat produced to melt metal? The combustion reaction of acetylene and oxygen is

$$2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(g)} + \text{energy}$$

DidYouKnow?

There are several forms of iron oxide, each with interesting, observable properties. Iron (II) oxide sometimes ignites spontaneously in air. Iron (III) oxide is called hematite, and is reddish brown in colour. Rouge is a specially purified form of iron (III) oxide, and Venetian red, which is largely iron (III) oxide, has been used to paint bridges, barns, and outdoor structures.

INQUIRY

INVESTIGATION 2-1

SKILLCHECK
- Initiating and Planning
- ✷ Performing and Recording
- ✷ Analyzing and Interpreting
- Communication and Teamwork

An Illuminating Experience

In this investigation you will investigate the products of combustion. The investigation is divided into three parts. Be sure to keep accurate records of the results of each part of the experiment.

Question

What are the products of the combustion of a candle?

Hypothesis

Formulate a hypothesis about what the reactants and products are in the combustion of a candle.

Safety Precautions

- Before lighting candles, make sure there are no flammable solvents nearby.
- Use care with matches.

Apparatus

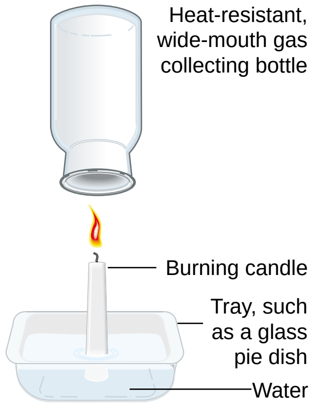
tray for water (15 cm x 20 cm)
gas-collecting bottle or glass jar
evaporating dish
all-purpose tongs

Materials

matches
candle (10 cm x 1 cm diameter)
ice cubes
aluminum foil
water

Procedure

① Make an observation chart similar to the one shown below.


Heat-resistant, wide-mouth gas collecting bottle
Burning candle
Tray, such as a glass pie dish
Water

Part 1

② Light the candle. Use a few drops of candle wax to secure the candle to the middle of the tray. Fill the tray two-thirds full of water.

③ While the candle is still burning, lower the inverted gas-collecting bottle or jar over the candle. Carefully **observe** what happens both to the candle and the level of water in the bottle.

④ **Record** observations on your chart and make inferences as to what happened.

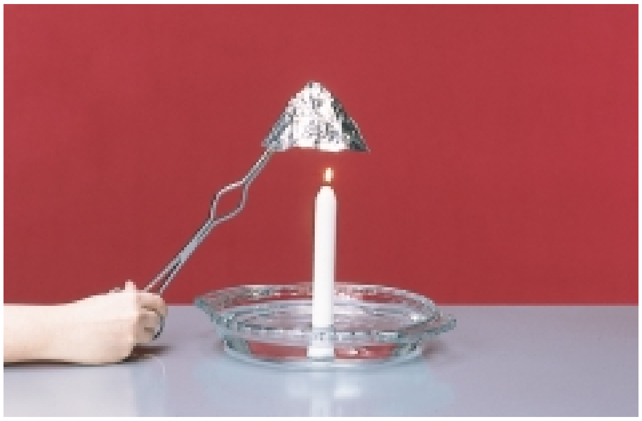
Part 2

⑤ Light the candle.

⑥ Place an ice cube in the heat-resistant evaporating dish. Hold the evaporating dish with the all-purpose tongs over the burning candle for 10 s.

⑦ **Record** your observations. There should be at least two significant observations.

Investigation	Observations	Inferences
Part 1		
Part 2		
Part 3		



Part 3

⑧ Cut a piece of aluminum foil in a circle that has a diameter of approximately 22 cm. Fold the circle of foil in half, and in half again. Cut a small hole at the corner where all folds meet. Open the foil to make a large cone with a hole in the middle.

⑨ Hold the cone with the all-purpose tongs and place it over the burning candle with the hole near the top of the flame. Be careful not to extinguish the flame.

⑩ Light a match. Hold it over the hole in the aluminum foil that is being held over the burning candle. Be careful not to burn yourself.

⑪ **Observe** and **record** your observations.

Analyze

1. What are the products of the combustion of a candle? What evidence supports your answer?

2. Which product(s) of combustion are most important to your daily life? Why?

3. Which part of the experiment illustrates one of the reactants needed for combustion? What is the reactant?

4. Which safety precautions did you follow while working near an open flame? How could you improve your awareness of safety during investigations?

Conclude and Apply

5. What is the chemical name and formula for the black substance found on the bottom of the evaporating dish in Part 2? Where could the black substance have come from? Explain.

6. Research on the Internet or in the library and write the chemical equation for the combustion of gasoline in an automobile. (Hint: The organic compound octane is found in gasoline.)

Products of Combustion

You have just investigated the products in the combustion of a candle. Another chemical reaction involving combustion occurs when propane is burned in a barbecue. Burning propane is an exothermic reaction that produces heat to cook the food. When the heat becomes too intense, sometimes the organic compounds in the meat or vegetables are chemically changed to pure carbon as seen by the black coating. The equation for the combustion of propane is shown below:

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)} + \text{energy (heat)}$$

propane + oxygen → carbon dioxide + water + energy (heat)

Compare the equation for the combustion of propane with the equation for the combustion of methane on page 149.

The products of combustion are not always beneficial. Burning wood or coal produces smoke and ash as well as heat. In addition, other substances are created by combustion. Soot, carbon monoxide, carbon dioxide, and oxides of sulfur and nitrogen can be created by the combustion of fuels such as coal, gas, and oil. Some products created when fuel is burned are pollutants. The brown haze that hangs over some cities is smog (see Figure 2.62). Smog is created when sunlight reacts with pollutant chemicals produced by burning fuels. You will learn more about pollution in Unit 3, Environmental Chemistry.

In the next activity you will observe several chemical reactions involving combustion.

Figure 2.62 Tiny particles of soot suspended in the air reduce visibility. These particles irritate the eyes and respiratory system.

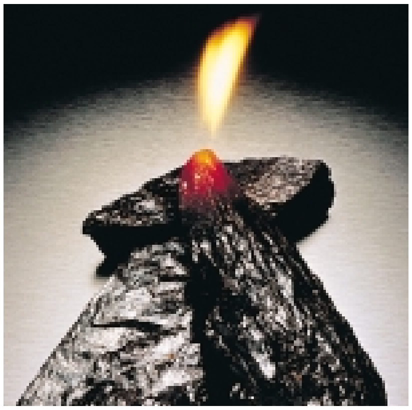
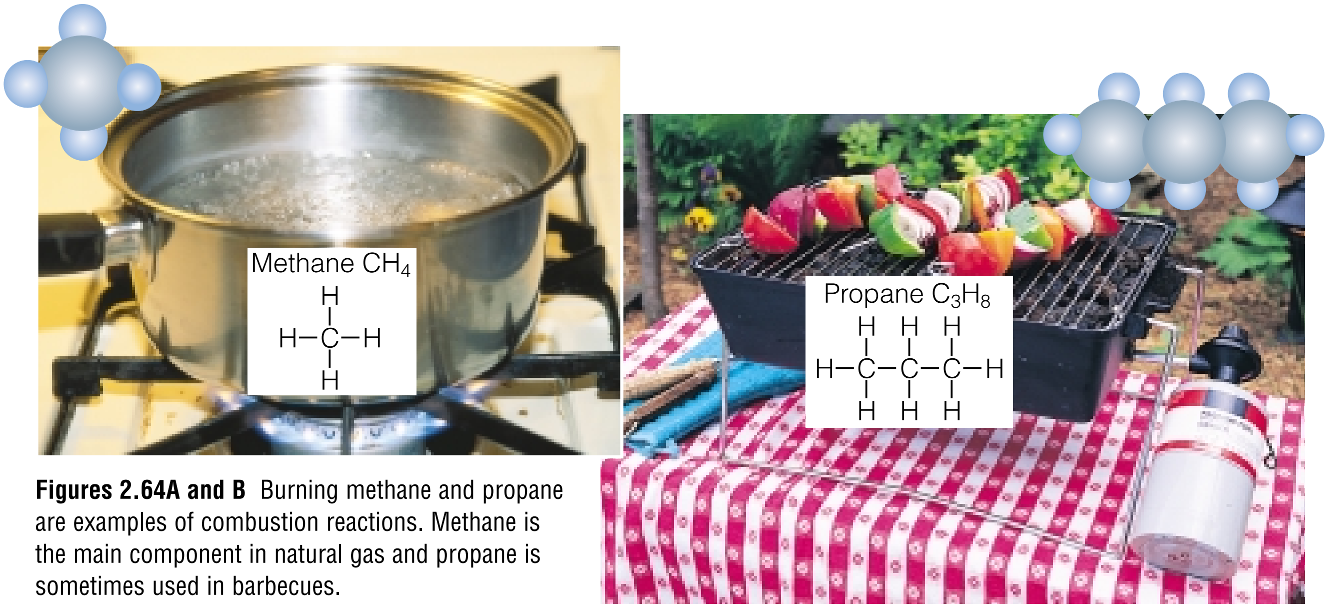


Figure 2.63 Coal is a chemical mixture of carbon, sulfur, and other elements. Which element do you suppose is burning in this picture? Which chemical reaction is occurring while the coal is burning?



Figures 2.64A and B Burning methane and propane are examples of combustion reactions. Methane is the main component in natural gas and propane is sometimes used in barbecues.

Find Out ACTIVITY

Where's the Fire?

Combustion can be a simple or complex reaction. In this activity you are going to study a few simple reactions involving combustion. Be sure to place used matches, burned wood, and marshmallows in the appropriate waste container provided by the teacher.

Safety Precautions

- Before striking a match, make sure there are no flammable solvents nearby.
- Use care with matches and burning materials.

Materials

2 wooden splints
evaporating dish
wax
toothpick
miniature marshmallow
watch glass
matches
sugar cube

Procedure

✷ Performing and Recording
✷ Communication and Teamwork

1. Prepare an observation chart to collect your data and observations.
2. Light a wooden splint and observe the chemical reaction of the burning of the wood. Brainstorm with your group and see if you can write a word equation for the reaction you have just seen.
3. Break up a second wooden splint into small pieces and set them in an evaporating dish. Light the bits of broken splint. How does this reaction compare with the first splint you burned? Keep the ash for use later in this Find Out Activity.
4. Place a small piece of wax on a watch glass. Use a match to try to light the wax and make it burn. What happens?
5. Place a toothpick in a piece of wax to use as a wick. Light the toothpick and observe. Record your observations.
6. Place a marshmallow on a watch glass. Light the marshmallow with a match. Observe the reaction and record.
7. Place a cube of sugar on a watch glass. Try to light the sugar cube. Observe and record the results. Add a small amount of wood ash from your wooden splint fire to the sugar cube. Try to light the ash. Record your observations.

What Did You Find Out?

✷ Analyzing and Interpreting

1. Write a word equation for the reaction you observed when you burned the wood.
2. Why were you not able to light the wax by itself or with the toothpick? (Hint: You are able to light candles made of wax.)
3. What are the products of combustion of a marshmallow?
4. What products are always made during combustion? How do you know?
5. What was the purpose of the ash you added to the sugar?
6. Describe the difference in burning times in steps 2 and 3. Explain why there was a difference.

Cool Tools

Virtual reality is the simulation of a real environment created by advanced technology. Headsets containing small screens can be used to view chemicals. Some chemists use cyberspace to build new compounds as shown in the picture to the right. The large purple ribbon-like molecule is an enzyme, while the blue is a DNA molecule. Chemists also use computers to predict the outcome of chemical reactions and the effect of catalysts. Computers provide a safe alternative starting point for the more dangerous experiments.

STRETCH Your Mind

Articles on board the *Titanic* spent many years in seawater before they were brought to the surface. Many were covered with corroded metals, sand, and other chemicals. Chemistry helped to restore these items. Electrolysis and another process, called electrophoresis, were used to remove the corrosion from leather, bank notes, and these casserole dishes. Electrophoresis is a technique of separating ions. The artifact is placed in an electrolyte solution and a current is applied. The current breaks up the dirt, salts, and other corroded materials as the particles move to the electrodes.

TOPIC 8 Review

1. List five ways you could increase the rate of a chemical reaction.
2. List five ways you could decrease the rate of a chemical reaction.
3. Explain the differences between the terms in each of the following pairs of words:
   (a) reactant, product
   (b) catalyst, inhibitor
   (c) chemical reaction, rate of reaction
4. In your own words, describe the effects of the following factors on the rate of a chemical reaction.
   (a) concentration
   (b) surface area
   (c) temperature
5. State a word equation for corrosion.
6. Describe the process of galvanization. Why are some metal products, such as nails and bolts, galvanized?
7. Why does a candle burn longer in the open than under an inverted glass jar?
8. What are some of the beneficial and harmful effects of burning fuels?
9. **Thinking Critically** Describe the similarities and differences between combustion and corrosion.

Wrap-up TOPICS 7-8

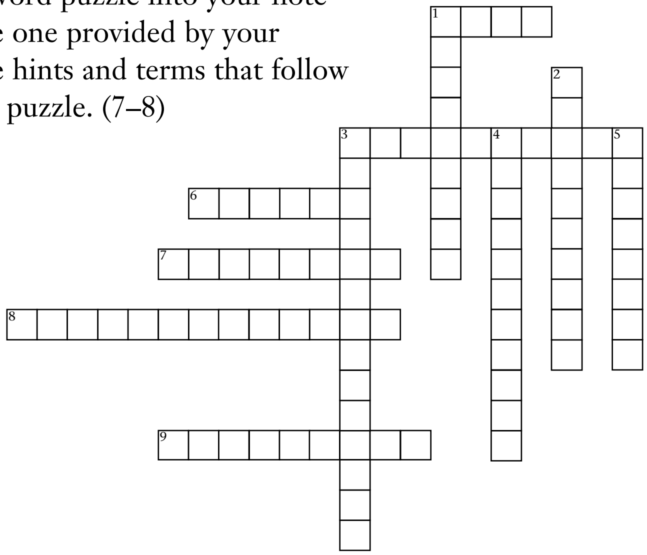
If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

chemical reaction
reactants
products
exothermic
endothermic
reaction rate
catalyst
enzyme
inhibitors
corrosion
rust
galvanization
combustion

Reviewing Key Terms

1. Copy the crossword puzzle into your notebook, or use the one provided by your teacher. Use the hints and terms that follow to complete the puzzle. (7–8)



Across
1. a type of corrosion
3. gives off energy
6. a type of catalyst
7. after the reaction
8. coat with zinc
9. slows down processes

Down
1. before the reaction
2. burning
3. deposit using currents
4. needs energy
5. speeding up, but not involved

Understanding Key Concepts

2. Is the following reaction endothermic or exothermic? How do you know? (7)

$$2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(g)} + \text{energy}$$

3. If you wanted to slow down a chemical reaction, what could you add? Give several examples. (8)

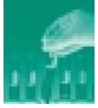
4. Give examples of three things that affect the rate of a chemical reaction. (8)

5. If you add a chemical to a test tube and the test tube becomes warmer, what can you infer? Give two different inferences. (7)

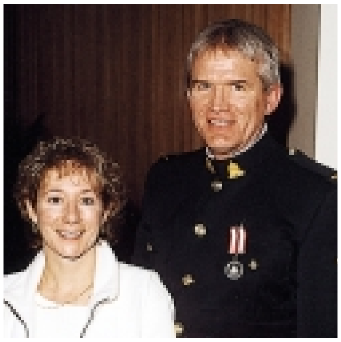
6. **Apply** Why are automobiles made with steel, which corrodes easily, instead of aluminum, which takes longer to completely corrode? (8)

7. **Thinking Critically** Give the word equation for photosynthesis and the word equation for respiration. Describe the similarities and differences between these two reactions. (7)

UNIT 2



Ask an Expert



When Merle Fuller was a student, he loved to read mystery novels and watch mystery shows. He liked not knowing who the villain was and using his deductive reasoning to solve the mystery. Today he works in a job that he says is just like living in a mystery novel. Merle is a forensic technician with the Lethbridge Police Department.

Q **What does a forensic technician do?**

A Forensics means evidence worthy of presentation in court or other judicial proceedings. Our job is to attend crime scenes, identify potential evidence, photograph and sketch evidence, and collect and preserve evidence. In short, the Forensic Identification Unit is about matching physical evidence found at a crime scene to a perpetrator. It is like playing a "who done it" game, but for real. We apply scientific methodology to police work in recording and collecting of evidence.

Q **What kind of evidence do you analyze?**

A Evidence can include hair and fibres at the point of entry; footwear impressions in snow, in sand, or on linoleum floors; blood spatter on clothing, floors, or walls; or latent (hidden or undetected) fingerprint impressions on just about any surface type. In recent years our evidence collection has also included DNA (deoxyribonucleic acid) analysis. DNA is like a biological-chemical fingerprint. Except for identical twins, everyone has his or her own unique DNA signature. This is an exciting addition to police work. Just a drop of blood, a flake of skin, or a single hair is often enough to solve a crime and identify the perpetrator.

Q **What tools do you use to analyze evidence?**

A We always use our cameras to show what the scene or material looked like before we did any work to it. Our notebooks are just as important as our cameras. We can never remember all the details of something we saw or did, so we record it all in our notebooks. We use fine silica fibres and camel-hair brushes to apply powder to items we want to dust for fingerprints.

Q **How do you use chemicals in your job?**

A We have a laboratory full of chemicals to help us develop fingerprints on paper, plastics, cardboard, and other smooth surfaces. Some of the chemicals we use enhance the detection of the fingerprints. Other chemicals are used to help locate and identify blood, urine, and other bodily fluids. We also have a special light that is used to project a laser powered ultraviolet light. This is called a Luma-Lite and is very useful in detecting bodily fluids and blood even after someone has tried to clean them up.

Q **Have you ever seen a crime scene without evidence left by the perpetrator?**

A Every perpetrator leaves a mark at a crime scene because every perpetrator has a unique style or method of doing things. Even if the perpetrator wears gloves, he or she has to get into the room somehow. A perpetrator will likely leave tool marks, footwear impressions, fibres, and even blood or skin cells. No one can enter a room without leaving something behind. A forensic technician needs to be persistent and dedicated enough to find the evidence.

Figure 2.67 A forensic technician might test clothing with an indicator that reacts with light. This glowing spot indicates the presence of blood.

EXPLORING Further

Invisible Formulas

Invisible ink has been used for hundreds of years to send secret codes, messages, and formulas to family members, government officials, and spies. You can use invisible ink to send a secret formula to your classmate. All you need are toothpicks, lemon juice, index cards, and a source of heat such as a candle or hot plate.

Dip the toothpick into the lemon juice and use it like a paintbrush to write one of the chemical formulas you have learned in this unit. Allow the card to dry for a few minutes. The formula and message will become invisible.

Exchange cards with someone. Light a candle and hold the index card at least 4 cm above the flame. You only want the heat from the candle to react with the chemicals on the paper. You do not want to burn the paper. The hidden formula should appear written in brown-black letters.

If you want your message to disappear again, gently dab a cotton ball soaked in household bleach on the index card. The carbon will disappear. Is the disappearance of the carbon another chemical reaction or is it a physical reaction? How could you find out?

Other invisible inks can be made with a mild solution of baking soda in water, or ammonia in water and milk. Try these inks and test whether the chemical reaction involving oxidation is as noticeable as the one you have just witnessed with lemon juice. What other juices might work?

DESIGN YOUR OWN

INVESTIGATION

Tough as Nails

Think About It

Corrosion is a common chemical reaction. Every year many items made of steel, such as railway tracks, bridges, and automobiles are slowly eaten away. Steel can be protected from oxidation if it is coated with a more active metal such as zinc. Zinc loses electrons to oxygen more readily than iron does, forming a tough protective layer of zinc oxide. The coating of zinc and zinc oxide prevents the formation of rust by keeping oxygen from reaching the iron.

The amount of corrosion that occurs is dependent on factors such as amount of moisture, amount of oxygen, type of metal, and whether a protective coating covers the metal. In this investigation you and your team members will study corrosion in Alberta and think of a question about corrosion you would like to investigate. Formulate your question based on information you have studied in this unit and information you may find by researching on the Internet. (Hint: Use the key words Alberta+corrosion+metals when you do your search.)

Your task is to think of a question to investigate about corrosion. Be sure to have your materials and experimental steps approved by your teacher before you assemble any materials or begin your investigation. You may use other metals, but consider using nails, which can be easily purchased at a local hardware store. You might investigate the protection provided by galvanizing nails. Or you might want to investigate the factors necessary to cause corrosion. The diagram of test tubes on this page indicates one possible experiment you could perform.

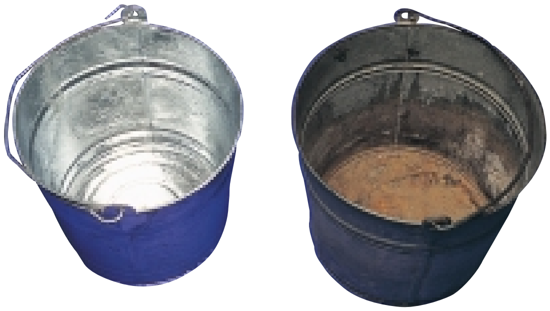
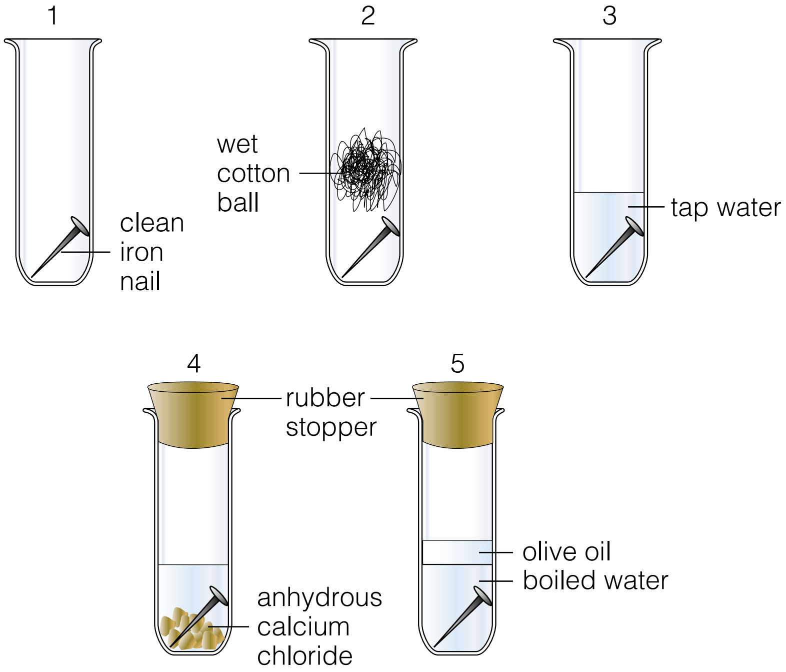
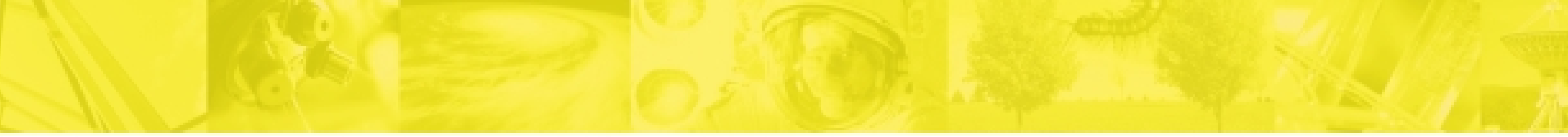


Figure 2.68 The bucket on the left has been galvanized.



Skill FOCUS

For tips on how to set up a controlled experiment, turn to Skill Focus 6.



Materials

Brainstorm a list of the materials that will be most appropriate in answering your question. You may also need electronic resources, art materials, or construction materials.

Safety Precautions

- Do not mix chemicals without your teacher's knowledge and approval.
- List additional safety precautions as you design your experiment.

Initiate and Plan

① With your group, decide on an experimental question to investigate. You might need to do some further research in order to decide on the question.

② Formulate a hypothesis or a prediction that will answer your question. Base your hypothesis on previous knowledge and on inferences that you can make as a result of that knowledge.

③ Design an experiment to test your hypothesis or prediction. Use words and diagrams to explain your design. Think about the order in which you could carry out the steps in your procedure. Decide on the feature you will change (the manipulated variable) and the feature you will observe changing (the responding variable). Decide what your control will be. You might find it helpful to refer to the Experimental Design Checklist.

Perform and Record

(Test Your Hypothesis)

④ Set up and perform your experiment. If necessary, carry out second and third trials. Make any modification to your experiment, if necessary.

⑤ Gather and record data and observations as you conduct your experiment. Decide how to record and present your data in a clear format (table, graph, diagram, etc.).

Analyze and Interpret

(Draw Conclusions)

⑥ Draw conclusions based on the results of your experiment. Discuss your conclusions with your group.

⑦ Did your findings support your hypothesis? Explain.

⑧ Write up your findings in a laboratory report. Be sure to include the following:

- Introduction
- Hypothesis or Prediction
- Procedure (step by step), including a diagram
- Data/Observations in the form of words combined with graphs, tables, etc.
- Conclusions

Experimental Design Checklist

1. Have you clearly stated the purpose of your experiment, the question you want to answer?
2. Have you written your best guess (hypothesis) about what you expect the answer will be?
3. Have you written a step-by-step procedure?
4. Have you obtained all the information you need from a variety of sources?
5. Did you make a complete list of all the materials you need?
6. Have you identified all of the variables in your experiment?
7. Identify all sources of error that you can think of in your design.
8. Did you repeat your experiment several times? How many?

UNIT
2 Review

Unit at a Glance

- All chemicals should be treated with respect. The WHMIS safety symbols have been adopted to safeguard the classroom, home, and workplace.
- All matter is made of atoms and can exist in three states. Matter can be divided into mixtures and pure substances.
- Physical changes cause a change in state, shape, or size of matter.
- Chemical changes create new substances.
- Pure substances can be divided into elements and compounds. A chemical formula is used to describe elements and compounds.
- Elements are organized into a periodic table according to similarities in their properties. Many scientists, including Mendeleev, Dalton, Thomson, Rutherford, and Bohr helped to develop the modern view of the elements, compounds, and atoms.
- The law of conservation of mass and the law of definite composition help explain the behaviour of elements and compounds in chemical reactions.
- Atoms are composed of small particles including electrons, protons, and neutrons. Electrons have a tendency to be found in pairs.
- Elements can be divided into metals, non-metals, and metalloids depending on their physical and chemical properties.
- Chemical symbols are used to represent elements and compounds. Chemical equations are used to represent chemical reactions.
- Chemical reactions are indicated by the creation of heat, light, the presence of a precipitate or gas, or a change in colour or odour.
- Compounds can be identified as molecular or ionic. Compounds are named according to rules established by IUPAC.
- Exothermic reactions produce heat. Endothermic reactions require heat.
- Catalysts speed up chemical reactions. Inhibitors slow down chemical reactions.
- Some metals corrode when they are exposed to air and moisture.
- Combustion is a highly exothermic combination of a substance with oxygen.

Understanding Key Concepts

1. Draw and label the symbols for the eight main categories in the WHMIS system.
2. List one physical and one chemical property for each of these elements: carbon, neon, and silicon.
3. Give four examples of pure substances, three examples of solutions, and three examples of mechanical mixtures that you might encounter during an average day.
4. What is the difference between a metal and a non-metal? Give three examples of each. Write their chemical formulas in parentheses after the names.
5. Here are some answers to questions about Unit 2. Make a question for each answer that could appear on a test for the unit.
   (a) conservation of mass
   (b) endothermic reaction
   (c) physical properties
   (d) chemical reaction
6. Describe an investigation in which you could contain and compare the quantity of reactants and products in a chemical reaction.
7. Give two examples of common reactions that involve chemical change. Write chemical equations for the reactions.

8. Identify four conditions that affect rates of chemical reactions.

9. Describe the effects of corrosion. What measures can be taken to prevent corrosion?

10. Explain the difference between observation and theory. Give one example of each.

11. How could you distinguish between a physical reaction and a chemical reaction?

12. Draw and label sketches of the atomic models of Dalton, Thomson, and Bohr.

13. Using chemical equations, write the chemical reactions for the following: photosynthesis, combustion, and corrosion of iron.

14. Which groups are divided by the "staircase" on the periodic table? How do their properties differ?

15. What could Dalton's atomic theory explain about matter that the particle model could not?

16. Describe a physical change that is not easily reversed.

17. Refer to the photograph of solid carbon dioxide (dry ice) in water on this page. Is the fog created an example of a physical or chemical change? How do you know?

Developing Skills

18. Refer to the photograph of lightning on this page. Use a dictionary to define chemilumenescence. How does this property connect with information you have learned in this unit? (Hint: Consider physical and chemical properties.)

19. Think of a common substance found at home. Write down three of its physical properties. Describe some chemical tests you could perform to identify its chemical properties.

20. Write the word and chemical equations for this reaction: sodium chloride is produced from the reaction of solid sodium with chlorine gas.

21. Using the table, answer the following questions:
    (a) Which of the substances are gases at 60°C? At −60°C?
    (b) Which of the substances are liquids at 60°C? At −60°C?
    (c) Which of the substances are solids at 60°C? At −60°C?

Substance	Boiling point °C	Freezing point °C
bromine	58	−7
propane	−42	−188
silver	2212	961
mercury	357	−39
radon	−62	−71

Problem Solving/Applying

22. Classify the following elements as metals, nonmetals, or metalloids:

(a) silicon
(b) neon
(c) lithium
(d) hydrogen
(e) boron
(f) phosphorous

23. Name the compounds and state whether each is ionic or molecular:

(a) CaS
(b) NO
(c) H_2O
(d) AlN
(e) SO_3
(f) CO
(g) AgI
(f) Fe_2O_3
(f) $CaCl_2$

24. Baking soda has the formula $NaHCO_3$. How are the properties of this compound different from the properties of the elements from which it was made?

25. During an experiment, two solid compounds burn in the presence of oxygen. Can you conclude that they are the same compound? Why or why not?

26. Describe an experiment you could perform to determine if a reaction is exothermic or endothermic.

27. What does the formula C_2H_6O tell you about the substance it represents? Be specific in your answer.

Critical Thinking

28. How are salt and a diamond similar? How are they different?

29. If you place a salty cracker in your mouth and start to chew it slowly, it will begin to taste sweet. Use your knowledge of chemical reactions to explain why this happens.

30. Sucrose breaks down slowly in water to form smaller sugar molecules like glucose. If a small amount of acid is added to the water, the reaction will happen much faster. The acid is not used up in the reaction. Explain the role of the acid in the reaction and give it a chemical name.

31. Propane is often used to cook food on an outdoor barbecue. Write a chemical equation for the reaction taking place when the propane is ignited. Write a word equation for what happens to food as it is cooked on the barbecue.

32. List one piece of evidence you would expect to see indicating a chemical reaction is taking place in each of the following situations:

(a) A candle is burning.
(b) Baking soda reacts with vinegar.
(c) A glass of milk is left on the kitchen counter for a week.
(d) A bagel is burned in the toaster.

33. Why might it be impossible to chemically change copper into gold as the alchemists tried to do?

34. Using a bag of microwave popcorn as an example, describe an experiment to illustrate the law of conservation of mass.

35. What difficulties would arise if materials were classified by appearance rather than composition?

36. Examine the photograph on this page. A pacemaker is a device inserted in the body to help regulate the rhythm of the heart. The battery that powers a pacemaker is often made with lithium. Which properties make lithium a good choice for the battery? Which properties of lithium could be a source of problems for this application?

37. A beaker containing a substance becomes cooler when you add another substance to it. What can you infer from this observation?

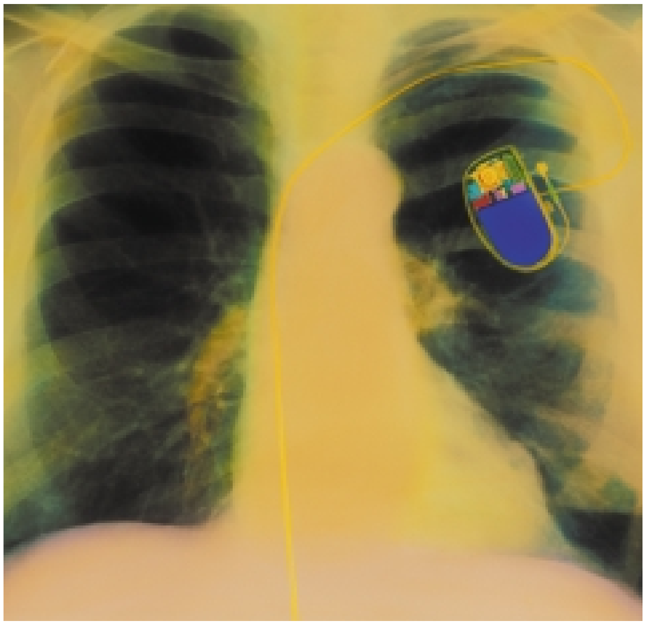
38. A beaker of coloured water becomes warm as it sits in the sunlight. Has a chemical reaction occurred? Explain.

39. How has understanding the atom changed the way scientists investigate chemistry?

40. List two elements and two compounds that can be dangerous to human health and/or the environment. Explain the danger of each, and identify the WHMIS symbols that should be labelled.

Pause& Reflect

Turn back to page 90 and reread the Focussing questions. For each question make a mind map (web) connecting the information you have learned in this unit. What other questions do you have about chemistry?



UNIT 3

Environmental Chemistry

Could we survive without chemicals? Our knowledge of chemicals and how they combine and interact enables us to produce medicines to fight hostile microbe invaders. We can create additives to increase yields of plant and animal food sources, and chemical agents to eliminate the pests that destroy these food sources. Our industries produce the synthetics that we use in our clothing and building materials. Most important of all, our bodies are made up of chemicals. Without chemicals, we would cease to exist!

Chemicals can seem benign—think of that harmless little shower of salt that you sprinkle on your fries. Or is it harmless? What about the salt we spread on icy roads in winter? It melts the ice, making our roads safer for driving. It also damages soil and growing plants. It runs into water courses where it may adversely affect fish, water plants, and the organisms that eat them. Clearly, we need to know what amounts of chemicals are toxic and how we might counteract any damage they cause. We need to understand the negative as well as the positive aspects of the interaction of chemicals with other substances.

In this unit, you will see some of the ways that we have made use of chemicals to improve our lives. You will also come to recognize the environmental costs associated with some of these lifestyle improvements. As a result, you will further develop your skill in the process of dealing with issues associated with our use of chemicals, and in developing alternatives that will help contribute to their safe, responsible use.

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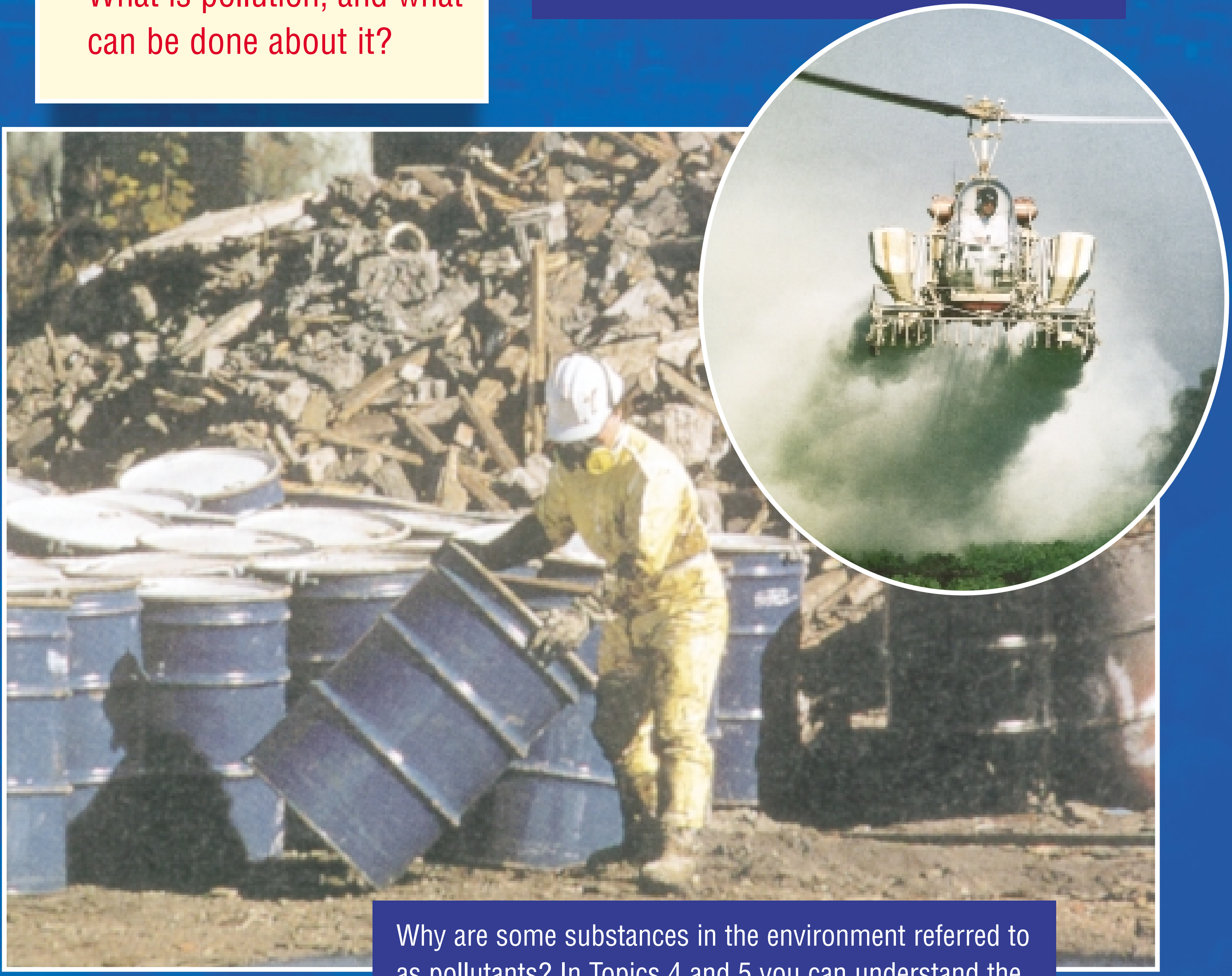
UNIT 3 Preview

Focussing Questions

- What do our bodies need in order to remain healthy?
- What are we ingesting along with our food, water, and the air we breathe?
- What is pollution, and what can be done about it?

Human beings require specific nutrients and chemicals to build strong, healthy bodies. What nutrients DO we need, and where do we get them? What is a suitable response when other organisms compete with us for the same nutrients? What scientific information do you need, in order to assess risks to the environment when those other organisms are eliminated? Find the answer to these and other questions in Topics 1–3.



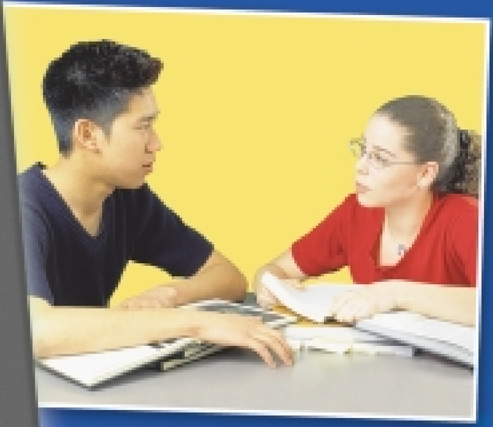
Why are some substances in the environment referred to as pollutants? In Topics 4 and 5 you can understand the basis for assessing how and why pollution is a problem.

What issues become clear when you study the environment from a chemical perspective? How are decisions made about these issues? Find out in Topic 6.

Looking Ahead

Read page 256, "A Simulation: Not In My Backyard." With your group, you will be assigned the role of a concerned party making a decision about the construction of a fertilizer plant in your "backyard." You can begin preparing right away.

- Start reading the newspaper for related articles.
- Watch the daily or evening news for stories of similar meetings.
- Gather background information from related sites on the Internet.
- Practise your decision-making skills by completing Investigations 3-C and 3-J.



TOPIC 1 A Hair-raising Dilemma

Take two of these and call me in the morning.

Figure 3.1 How does a doctor decide which chemical substance to prescribe for a patient? Could that substance be in a rock?

Imagine you are a doctor faced with the following problem. Your patient, a 70-year-old male, is complaining of an intense burning pain in his feet. The pain is so severe that he has had to give up his daily walk. The burning sensation in his feet eases when he is resting, but is still noticeable. Lately it is uncomfortable for him to even wear shoes. He has also noticed a burning sensation in his left arm and chest, after walking even short distances on level ground.

Your first thought might be "Hmm. Chest pain when exercising — this sounds like heart trouble. But what's that burning sensation in his feet? That couldn't be heart-related, could it?" You ask your patient questions to gather more information.

You learn that he eats healthy foods, but has some food allergies or intolerances. Could that be it? You order tests, including a chemical analysis of the patient's hair!

Take Two Pebbles...

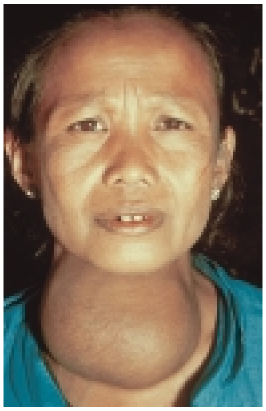
Why would you request an analysis of your patient's hair? What does his hair have to do with what he eats? You aren't likely to prescribe two chunks of rock to your patient, as the doctor in the cartoon is doing, but what does that really mean? What does the patient's diet have to do with the substances contained in rocks? And how does any of this affect your and your patient's decisions about his future treatment? Perhaps the test results will help answer some of those questions. While you and your patient await the test results, you have to consider his comfort level. Should you prescribe painkillers?

You discuss the problem with your patient. You tell him that his body is made up of chemicals, as is his food. The process of digestion breaks down the chemicals in the food into small, soluble molecules, which then pass through membranes into the blood vessels. In the blood, these chemicals (**nutrients**) circulate through the body to the cells where they are used for energy, growth, body building, and cell repair. These nutrients can be divided into two major groups, organic and inorganic.

The organic (carbon-containing) nutrients are classed as **carbohydrates**, **proteins**, **lipids**, and **vitamins**. Only green plants can form many of the organic compounds, while animals modify others. Regardless of the dietary source, they are essential for health.

DidYouKnow?

Goitre, a swelling of the thyroid gland at the base of the neck, is often caused by iodine deficiency. It is a common problem in many parts of the world, particularly where sea products are not frequently eaten.



Chemicals in the body transform these basic materials into more complex chemical materials. Table 3.1 shows you the dietary sources of carbohydrates, proteins, and lipids.

Table 3.1 Dietary Sources of Nutrients

Organic molecule	Role in nutrition	Typical Dietary Sources
carbohydrates	energy source for metabolism	• rice • grains • potatoes • fruits
proteins	structural molecule for body and helps chemical reactions	• meat • eggs • dairy products • legumes • nuts
lipids	storage of unused chemical energy	• vegetable oils • nut oils • some dairy products

Inorganic substances that are not destroyed by cooking or exposure to air are referred to as minerals. Mineral requirements are distinguished by the amount needed: **macromineral** (100 mg/day or more) or **trace element** (less than 100 mg/day). These minerals are essential components in **enzymes** (special protein molecules that regulate chemical reactions in living organisms) and vitamins (large organic molecules that help the enzymes function). Vitamins are a good example of nutrients that the human body cannot make itself and must get from food.

Now, what does this have to do with those two chunks of rock you see the doctor prescribing in the cartoon in Figure 3.1? Some of Earth's elements are examples of the chemicals the body needs in order to remain healthy. Sixteen of the naturally occurring elements occur in all living organisms. Green plants require 18 different elements for proper growth and functioning; humans require at least 22. You may recall from your Grade 8 science course that rock is made up of minerals and that minerals are elements or compounds. Table 3.2 on page 180 shows how elements are used in the human body.

Math CONNECT

The four most common elements in your body (by percent of wet mass) are oxygen (65 percent), carbon (18 percent), hydrogen (10 percent), and nitrogen (3 percent). Hydrogen and oxygen occur mainly in the form of water (H_2O), which makes up about 60 percent of your mass. Use the values given, to produce a circle graph that shows the chemical composition of your body. What percentage is composed of other elements not named? Use your computer to create the graph.

Pause& Reflect

Adding fluorine, in the form of fluoride, to water supplies is expected to decrease the amount of money paid by the Canadian health care system for dental care. This is obviously beneficial, so why do people oppose fluoridation of municipal water supplies in many locations? Write your speculations on this issue in your Science Log.

DidYouKnow?

Vitamin C helps form the connective tissue that holds our skin, muscles, blood vessels, and other body structures together. Humans are one of the few species of animals that cannot make vitamin C within their own bodies. Scurvy, a disease resulting from a lack of vitamin C in the diet, results in bleeding gums, loss of teeth, and bruising. Although scurvy is not fatal, it decreases resistance to other deadly diseases. British sailors in the 1700s were referred to as “Limeys” because of the lemons (called “limes” at that time) they ate to avoid scurvy.

Table 3.2 The Role of Elements in the Human Body

Element name	Role in the human body
calcium	crucial in nerve conduction, muscle contraction, blood clotting, proper functioning of cell membranes; forms bones and teeth
phosphorus	promotes proper bone formation, regulates metabolism, forms compounds that store and release energy
magnesium	component of bones and teeth, essential to enzyme function, helps regulate nerve activity
sodium	helps regulate nerve impulses in nerves and muscles
potassium	helps regulate nerve signals and muscle activity, involved in protein formation, required to regulate the acid/base balance
sulfur	elemental sulfur is not utilized, BUT sulfur in amino acids is the basis of all proteins
chlorine	helps regulate water balance, plays a role in proper cell membrane function, component of hydrochloric acid in the stomach
iron	crucial part of red blood cells that regulates oxygen transport
zinc	essential component of enzymes regulating protein formation and carbohydrate metabolism
iodine	major component of thyroid hormones, which regulate metabolism
selenium	component of an antioxidant enzyme that helps prevent decay of cell function
copper	promotes iron absorption and utilization, is a component of many enzymes, helps regulate nerve activity
manganese	component of some enzymes, involved in bone formation and protein metabolism
fluorine	helps regulate calcium deposition
chromium	activates vitamin B3 to control use of blood sugar in energy production
molybdenum	key component of three enzymes that regulate metabolism
cobalt	component of vitamin B12, which helps regulate red blood cells

Off the Wall

During the *Apollo 15* mission, astronauts David Scott and James Irwin landed on the Moon. Although both astronauts were in excellent health before leaving Earth, both Scott and Irwin developed irregular heart rhythm during moments of high exertion and stress. NASA doctors, concerned that low gravity might have some negative effect on humans, tested both astronauts upon their return to Earth. The doctors found that Scott and Irwin had low potassium levels from eating the highly refined, prepared foods that were supplied to them. As a result of their findings, potassium-enriched food and snacks were added to the menu of subsequent space missions.

A Balanced Approach

Although your patient has a healthy diet, he has developed an intolerance for certain foods over the years, so he tends to avoid those. He feels healthy, and he tries to eat according to Canada’s Food Guide for the most part, so he doesn’t see a problem with avoiding food groups that cause problems for him.

You and he decide that he will not take any painkillers for the time being. Everything the human body takes in has an effect on it. The chemicals in a painkiller might react with other chemicals in the patient’s body, making diagnosis difficult. As well, if the painkillers mask the pain, the patient might decide not to bother following up on the problem, which may then worsen to the point where his body is damaged permanently. When you see the test results, you are not surprised. Your patient had a calcium level well below normal, and correspondingly low amounts of magnesium, copper, manganese, zinc, chromium, and selenium. His food allergies either caused him to avoid certain foods or prevented him from absorbing enough of the necessary chemicals from the foods he did eat.

You explain that this inability to digest foods can be caused by an inflammation of the digestive tract, which slows down normal absorption. This could be the cause of your patient's worrisome chest pain. You run further tests to find out if this is the case.

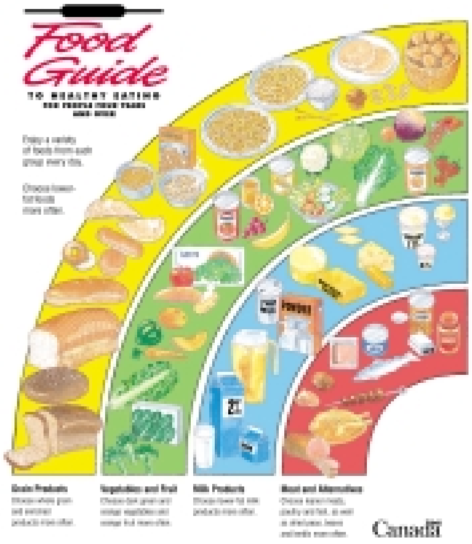


Figure 3.2 This Health Canada food guide recommends your daily intake of nutrients.

When the test results come back, you realize that your patient has a chemical imbalance, as well as an inability to digest some of the chemicals his body requires. How can you correct this problem? Chemicals to the rescue! Those two chunks of rock might be helpful after all — you prescribe 1000 mg/day of calcium and 400 mg of magnesium to correct the arterial spasm that caused the chest pain. The burning feet? They were a symptom of inflamed nerves, and the 50–100 mg doses of B-complex vitamins you prescribed relieved those symptoms.

Six months have gone by since you started your patient on his new diet. As you watch him walk out of your office with a spring in his step and a clean bill of health, you reflect on the crucial roles of chemicals in the human body and the importance of keeping them in balance, as indicated in the Food Guide in Figure 3.2.

The Root Source

All living things need a constant supply of raw materials and energy to produce new cells for growth, to repair damage caused by normal wear and tear, and to remain healthy. For humans, most of the elements we need are found in the soil. Even if we could eat soil, it would do us little good. The elements are found in such low concentrations that we would have to eat enormous amounts of soil just to get the minimum amount of elements needed. It is a good thing that plants can extract the minerals for us — by some estimates as much as 6 000 000 000 t every year!

Word CONNECT

Life: the condition that distinguishes active animals and plants from inorganic matter, including the capacity for growth, functional activity, and continual change preceding death.

Find two definitions of *life* in various dictionaries and write them in your notebook.

The root systems of plants are uniquely suited for extracting minerals. Roots are covered with tiny "root hairs" to increase the surface area for absorption. They branch again and again as they grow, to get the most contact with water in the soil. Minerals dissolved in the water are taken up and concentrated into the root hairs. In some cases, the root hairs are able to produce mineral concentrations up to 10 000 times greater than the soil around them. The minerals absorbed by the roots move to other parts of the plant, where they are used to build organic compounds such as vitamins, proteins, and lipids. When we eat these plants, we access these valuable organic compounds. For example, compare the amounts of minerals present in plants versus that in human tissue and Earth's crust, as shown in Table 3.3. Which of the elements listed for Earth's crust are present in greater amounts in plants? In animals? Did you notice that the elements found in the largest amounts in humans and plants are not necessarily those that are most abundant in the crust?

Plants are essential to our health and survival. Without plants, we would not be able to obtain the nutrients we need. That is why many scientists are interested in what affects the development and growth of plants. In the next investigation, you will measure the effects of the addition of nutrients on the rate of seed germination and growth.

DidYouKnow?

In 1930, Howard Dittmer at the State University of Iowa placed a single winter rye plant (*Secale cereale*) in a box of soil about 30 cm long, 30 cm wide, and 56 cm deep. Four months later, Professor Dittmer carefully freed the root system of that single rye plant and measured it. He was astonished to find that the total length of the root system was nearly 11 000 km (equal to about a quarter of the circumference of Earth) with a surface area of about 630 m^2 (the floor space of four or five houses).

Table 3.3 Comparison of the Elemental Composition of Earth's Crust, a Generic Plant, and a Human

Element	Symbol	Approximate % (by mass) of Earth's crust	Approximate % (by mass) of a generic plant	Approximate % (by mass) of a human
oxygen	O	49	75	65
carbon	C	0.09	13	18
hydrogen	H	0.88	10	10
nitrogen	N	0.03	0.45	3.3
calcium	Ca	3.4	0.07	1.5
phosphorous	P	0.12	0.06	1.0
potassium	K	2.4	0.28	0.35
sulfur	S	0.05	0.05	0.25
sodium	Na	2.6	trace	0.24
chlorine	Cl	0.19	0.04	0.19
magnesium	Mg	1.9	0.06	0.05
iron	Fe	4.7	0.03	0.005
manganese	Mn	0.08	0.01	0.0003
silicon	Si	25	0.36	trace
all others		<0.03	trace or less	trace or less

Pause& Reflect

The only source of nitrogen for humans is from eating plants. Using Table 3.3, determine how many times more abundant nitrogen is in humans than in the Earth's crust. What is the role of nitrogen in the human body? Would adding more nitrogen to the soil around plants make nitrogen more available to humans? Write your speculations in your Science Log.

INQUIRY

INVESTIGATION 3-A

SKILLCHECK

- ✸ Initiating and Planning
- ✸ Performing and Recording
- ✸ Analyzing and Interpreting
- Communication and Teamwork

The Effects of Fertilizer Nutrients on Seed Germination and Growth

The growth and development of a plant from seed to mature form is affected by the amount of nutrients that the plant can extract from the environment and incorporate into its tissues. Growing plants require three essential elements for growth and reproduction. Phosphorus is necessary for seed germination, nitrogen is needed for stem and leaf growth, and potassium promotes flower and fruit formation. Commercial fertilizers are excellent sources for all three of these elements.

The numbers listed on a package of fertilizer refer, in order, to the amounts of nitrogen, phosphorus and potassium provided by that fertilizer. Under the same conditions, you might expect plant seeds to germinate (sprout) and grow at the same rate, but what if the conditions are not the same? How would changing the amount of a fertilizer affect the development and growth of a plant?

Question

How does the amount of a nutrient influence the growth and development of plants?

Hypothesis

Form a hypothesis about the effect of increasing nutrient levels on plant growth.

Safety Precautions

Apparatus

marker
scissors
50 mL graduated cylinder
four 50 mL beakers
stirring rod
metric ruler

Materials

5 Ziploc Bags
paper towels
25 seeds (mung beans or garden pea)
distilled water
commercial fertilizer
graph paper

Procedure

1. Label the 5 Ziploc™ bags: distilled water, 1 g, 5 g, 10 g, 15 g.

2. Cut paper towel into square pieces, sized to fit inside a Ziploc™ bag and place 2 squares in each bag.

3. Distribute 5 seeds inside each Ziploc™ bag between the plastic and paper towel. This will allow you to **observe** and **record** any changes to the seeds.

4. Add 5 to 10 mL of distilled water to the bag labeled distilled water, completely moistening the paper towel.

5. Using the graduated cylinder, prepare a solution of 1 g of the fertilizer in 25 mL of distilled water. Add 5 to 10 mL of this solution to the "1 g" Ziploc™ bag, making sure to completely moisten the paper towel. Save the remainder in a labeled beaker.

CONTINUED ▶

⑥ Repeat step 5 three more times substituting 5 g, 10 g, and 15 g of fertilizer in each case. Use the bags labeled “5 g”, “10 g” and “15 g.”

⑦ Make sure all bags are sealed tightly and place the bags in a dark, warm place designated by your teacher.

⑧ Examine the bags daily for 10 days. **Record** any changes that might have occurred. If the root is visible the seed is considered germinated.

⑨ Do not allow your towels to dry out. Moisten each bag with the appropriate solutions in equal amounts when necessary.

⑩ Each day, use the ruler to **measure** the root growth of each seed from the time it appears. **Record** the measurement.

⑪ Each day, use the ruler to **measure** any shoot (stem and leaf) growth from the time it appears. **Record** the measurement.

Analyze

1. Prepare line graphs to represent your results. Plot root growth on one graph, and shoot growth on a different graph. Use different colored pencils to represent each of the Ziploc™ bags.
2. What was the effect of increasing amount of fertilizer on root growth? On shoot growth?
3. From your observations, write a general statement about the effect of increasing nutrient levels on plant growth.

Conclude and Apply

1. What was the purpose of the bag of distilled water?
2. Did your findings support your hypothesis? Why or why not?
3. Read the label for the fertilizer that you used in this investigation. From the numbers listed for nitrogen and phosphorus for that fertilizer, would you expect a greater effect on root growth or shoot growth? Do your results confirm this expectation?

   A neighbour has a small (3 m^2) backyard garden plot and plans to scatter a bag of fertilizer over the plot “to help the vegetables get started.” What advice would you give your neighbour?

Skill FOCUS

To review writing a hypothesis and making predictions, turn to Skill Focus 6.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Despite the fact that phosphorus is an essential nutrient for plant growth, it is associated with environmental pollution. The demand for and production of “phosphate-free” soaps and detergents has been one response to the need to reduce phosphorus in the environment. Why is phosphorus a concern? What can be done about it? To find out, visit the above web site. Click on Web Links to find out where to go next. In your notebook, write a brief explanation for the concern about phosphates.

Commercial Fertilizers

The three numbers on a bag of commercial fertilizer (see 21-7-7 in the photograph, previous page) are a convenient signal for gardeners. Different fertilizer mixes aid the growth of different parts of a plant. Leaves, roots, and flowers benefit, respectively, from high nitrogen, high phosphorus, and high potassium content. The numbers, always in the same order, refer to the percentage of mass of the fertilizer mix that provides nitrogen, phosphorus, and potassium.

As shown in Figure 3.3, commercial fertilizers typically provide nitrogen in the form of three nitrogen compounds that imitate a natural process called the nitrogen cycle: nitrates, ammonia, and urea. Plants cannot take nitrogen directly from the atmosphere. Plant roots readily absorb nitrates dissolved in water, however, and plants use the nitrates to make proteins. Nitrates are formed in soil in a two-step process. A few species of soil bacteria can "fix" atmospheric nitrogen by forming ammonia, and other species can then change the ammonia to nitrates.

Phosphorus is provided in commercial fertilizers as phosphate compounds. The mineral potash is the source of potassium. The 21-7-7 signal to the gardener accounts for 35 percent of the mass of a fertilizer mix. Find out about the remainder in the next activity.

Figure 3.3 In many parts of the world, artificial fertilizers add excess nitrogen to the environment.

Word CONNECT

Kwashiorkor: A childhood disease associated with a low-protein diet. This lack of protein causes mental and physical deficiencies. A deficiency in protein occurs in animals because the only way they can get nitrogen to make their own proteins is by eating plants or other animals. Which deficiency disease is the result of a lack of iodine in the diet?

Find Out ACTIVITY

An Analysis of Fertilizer Nitrogen

The front label on a package of fertilizer lists the amounts of the major nutrients (N, P, K). If you look carefully, you will find another label giving the "Guaranteed Analysis" of the specific ingredients. In this activity you are asked to inspect and investigate the "Guaranteed Analysis" of a fertilizer.

Materials

fertilizer, preferably for use on lawns
access to the Internet

Procedure ✷ Performing and Recording

1. Examine the label listing the "Guaranteed Analysis" on the package of fertilizer. List the three ingredients that provide nitrogen from the most to the least amount.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Investigate why three types of nitrogen compounds are being used. In paragraph form, outline the results of your investigation. Be sure to include the reason each compound is included as an ingredient.

2. You will notice that iron (Fe) is one of the listed ingredients. What is the role of iron in a fertilizer?

Issues Emerging from High Productivity

Until the early 1900s, plants received nitrates only from nature. The production of artificial fertilizers changed that by increasing nitrogen levels available for plants. The use of artificial fertilizers and other human activities have increased the amount of nitrogen in the environment — by as much as 140 000 000 t per year!

The effect of this extra nitrogen is increased plant growth. Since 1950, crop production has doubled worldwide due to the use of artificial fertilizers and the development of high-yield food crops such as the one shown in Figure 3.4. These high-yield varieties have allowed most countries to increase food production dramatically. Land barely suitable for farming can yield large crops when planted with high-yield varieties and fertilized and watered well. This seems entirely positive, but consider the following issues.

Figure 3.4 What issues are associated with developing and maintaining the high yield of this corn field?

It takes a lot of fertilizer and water to produce a crop of high-yield varieties — a very expensive proposition for farmers. In addition, the planting of only one crop increases the chance of a disease spreading through the entire crop. A variety of plants usually means at least one crop might survive a disease. Chemical agents (pesticides) reduce the amount of crops lost to damage or disease, but they exact a cost — in dollars and environmental impact. The next Topic introduces you to the nature of a pesticide and what some of those costs can be.

TOPIC 1 Review

1. Describe the function of each of the following minerals in our bodies:

(a) phosphorus
(b) potassium
(c) iodine
(d) cobalt

2. What is the difference between a macromineral and a trace element?

3. Plants are a source of energy for human nutrition. Describe other nutritional needs that humans may meet by eating plants.

4. **Apply** Why are fertilizers available with different amounts of nitrates, phosphates, and potash?

5. **Thinking Critically** Vitamin D forms in our bodies in the presence of ultraviolet light from the Sun and can also be obtained through dietary sources. The Inuit people of the far north do not get enough ultraviolet light to form any significant amount of vitamin D, so where do the Inuit get their vitamin D?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To learn more about vitamin D, go to the web site above. Click on Web Links to find out where to go next. In your notebook, write a brief summary of the main role of vitamin D in the human body.

TOPIC 2

A Growing Concern

Figure 3.5 The application of insecticides, herbicides, and water can increase food production for people.

In a normal healthy ecosystem, many species may access the same food source. But human beings have an advantage — agriculture allows us to carefully nurture a select group of plants for our use. To maximize the quantity of plants we can harvest, we control other species who compete for these plants. For example, if we grow potatoes, we might actively discourage potato beetles in our fields. In other cases, we hinder the growth of other plants that would compete with our crops for soil resources. Spraying crops with **pesticides** to control "pests," as shown in Figure 3.5, has become standard practice worldwide. Most pesticides are designed to affect only specific types of pest species. **Herbicides**, **insecticides**, and **fungicides** control weeds, insects, and fungus pests. Dealing with insect pests has long been the target of scientific and technological attention. The citronella candles and mosquito coils you burn to keep mosquitoes away from your deck or camp just send the insects away. Chemical sprays such as dieldrin and DDT actually kill the insects, raising issues which were not immediately recognized, as you will see in the next section.

Pause& Reflect

Do you think it is possible to develop a system of agricultural production that is not affected by pests and by crop and livestock diseases? Include reasons for your answer in your Science Log.

Issues Associated with the Use of DDT

The invention of DDT by the Swiss chemist Paul Hermann Müller was originally seen as one of the greatest advances in medicine during the twentieth century. Toward the end of World War II, the disease typhus (transmitted by lice) threatened 1.3 million Allied troops. This is the same disease that totally wiped out Napoleon's Grand Army on its retreat from Russia in the 1800s. The application of DDT completely removed the typhus threat. DDT proved so successful in controlling insect infestations that Paul Müller was awarded the 1948 Nobel Prize in Physiology or Medicine for "his discovery of the high efficiency of DDT as a contact poison against several arthropods."

In the 1950s it was hoped that DDT would prove equally effective in stamping out malaria. Each year, this mosquito-transmitted disease affects over 120 million people and is responsible for over 1 million deaths. In the next investigation, you will explore the scientific basis for explaining unforeseen consequences of introducing DDT into the environment.

Pause& Reflect

In 1955, the World Health Organization (WHO) sprayed dieldrin, a chemical pesticide similar to DDT, on north Borneo to control malarial mosquitoes. Although the mosquitoes were almost completely eliminated, so were the lizards that fed on the dead insects. Island cats that preyed on the lizards soon began dying as well, leading to an explosion of the rodent population as their natural predator died off. Plague carried by fleas on the rodents was a serious threat to the islanders until the British Air Force (on request by WHO) parachuted cats onto Borneo.

In your Science Log, write a short paragraph reflecting on how an understanding of the food chain could inform issues associated with killing insect pests.

THINK & LINK

INVESTIGATION 3-B

SKILLCHECK

Initiating and Planning

☀ Performing and Recording

Analyzing and Interpreting

☀ Communication and Teamwork

DDT in a Food Chain

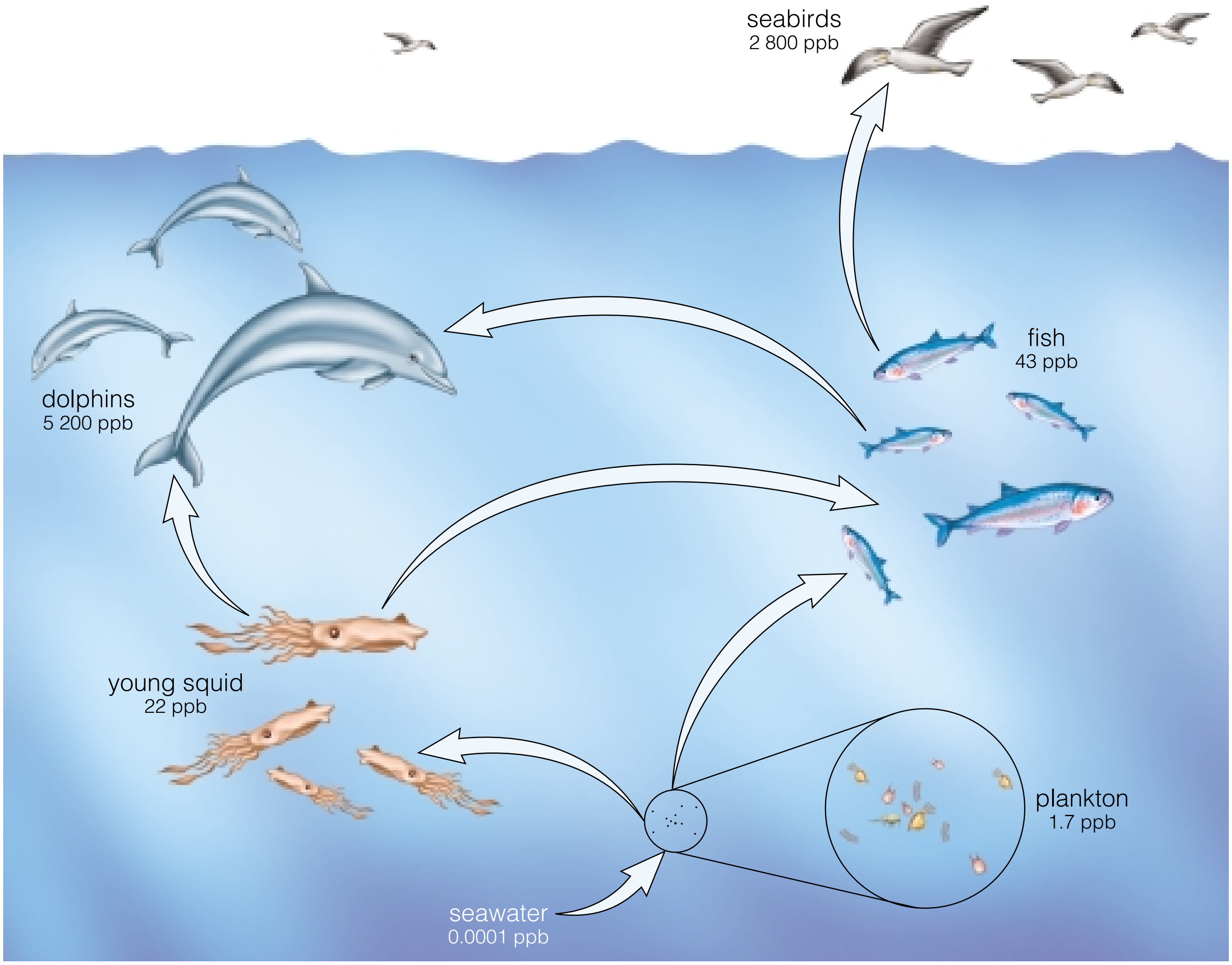
Think About It

DDT (dichlorodiphenyltrichloroethane) is an example of a persistent pesticide that can remain in the environment for long periods of time. The longer a pesticide is present in the environment, the greater the chance that it will be consumed by organisms. Some pesticides can accumulate in the bodies of organisms. As a result, they can increase in concentration in specific tissues or organs. How do pesticides, such as DDT, enter food chains? In this investigation, you will trace the path of DDT in a north Pacific Ocean food chain.

What to Do

❶ Study the following food web. Below the name of each organism is a number that indicates the amount of DDT in the organism's tissues, in parts per billion (ppb). One ppb is equivalent to 1 mg/1000 L.

❷ Use the food web and the information about DDT on page 190 to answer the questions that follow.



DDT in a north Pacific Ocean food web, in parts per billion (ppb). The arrows show the flow of energy from one "trophic," or feeding, level to another. Seabirds feed on fish, so seabirds are at a higher feeding level than fish.

CONTINUED ▶

The DDT Story

The risks of using pesticides in ecosystems first became widely known during the 1950s and 1960s, when the toxic effects of the insecticide DDT were recorded. DDT was one of the first and most powerful insecticides developed. During World War II, it was used to control populations of insects (such as body lice, fleas, and mosquitoes) that can transmit deadly diseases to people. As a result, the rate of death from malaria, bubonic plague, typhus, and yellow fever fell dramatically. DDT was also used widely on crops to control damage caused by insect pests.

In 1962 biologist and writer Rachel Carson published a book entitled *Silent Spring*, which described how pesticides had spread throughout the environment. As a result of her scientific evidence and the demands from an alarmed public, the use of DDT was severely restricted in Canada after 1969. DDT has not been registered for use in Canada since the mid-1980s.

Rachel Carson

About ten years after the first use of DDT, signs of trouble appeared. Dead birds, fish, frogs, and other animals were found in areas that had been heavily sprayed with DDT. The fat in their bodies contained high levels of the insecticide. Harmless or beneficial insects, such as butterflies and honeybees, also started to disappear from areas that had been sprayed.

Tests of soil and water showed that DDT remained in the environment for many years. For example, DDT was still found in the soil of some heavily sprayed orchards ten years after the spraying was stopped. DDT was also found in the bodies of many different organisms in areas around the world where the insecticide had never been used. It also began showing up in the tissues of people.

Pesticides can severely affect the reproduction of birds of prey, such as this osprey.

An unexpected outcome of using DDT was its effect on populations of birds of prey. The numbers of hawks, eagles, and ospreys on farmlands across North America and Europe fell sharply during the 1950s and 1960s. Scientists discovered that DDT reduced the ability of these birds to produce normal eggshells. Affected birds laid eggs with thin shells that broke in the nest, so they were unable to produce the usual number of young. The adult birds had accumulated DDT in their bodies from the fish they ate. The amount of DDT had accumulated in the bodies of organisms, moving from producers to primary consumers, to secondary consumers, and so on. This process is called **biological magnification** or **biomagnification**. Eventually concentrations of DDT became large enough in birds of prey to affect their reproduction. Unfortunately, DDT continues to be used in some tropical countries because it is such an effective pesticide. It not only affects species that live in these countries but also species that live elsewhere in the world, including people who consume food products imported from the tropics.

DidYouKnow?

One part per billion (ppb) is equal to one glazed doughnut in a chain of doughnuts circling Earth two and a half times.

Analyze

1. How does DDT enter a food web?
2. Which organism shown in the food web on page 189 contains the most DDT?
3. Which organism is at a higher trophic level, dolphins or plankton?
4. What is the relationship between the trophic level of an organism and the concentration of DDT in its body?
5. In the food web on page 189, how many times greater is the concentration of DDT in the fish than in the seawater? How many times greater is it in the dolphins than in the seawater?
6. In your own words, explain why animals at the top of a food chain are particularly at risk from poisons in the environment.

Conclude and Apply

7. Use an example to explain how an animal living hundreds of kilometres from an area sprayed with DDT might get DDT in its body.
8. DDT is stored in body fat and remains toxic for many years. Explain why these characteristics are undesirable in a pesticide. What characteristics would you want in a pesticide to make it less harmful to non-pest organisms?

Extend Your Knowledge and Skills

9. After spraying crops with DDT for several years, farmers found that populations of insect pests rebounded. One reason was that the insects had developed resistance to the insecticide. Suggest another reason, based on what you know about populations, food pyramids, predators, and competitors.
10. When Rachel Carson published her book about the effects of pesticides on food chains and people, she had many opponents. Use your local library and/or the Internet to research Rachel Carson. How did she present her ideas to the general public and the scientific community? What methods would you use to inform people of a threat to the environment? Why were Rachel Carson's ideas initially opposed?
11. The table below gives DDT levels, in parts per million (ppm), found in the eggs of three species of seabirds. The eggs were sampled from two different locations along Canada's east coast. Pesticide levels found in birds' eggs are a good indicator of pesticide levels in the environment. Study the data and answer the questions that follow.

DDT Level in Atlantic Seabird Eggs

Species	Year	DDT level in eggs (ppm) Bay of Fundy	DDT level in eggs (ppm) Atlantic Ocean
Leach's storm-petrel (feeds on small organisms near the surface of the water)	1968	no data	1.46
	1972	6.81	2.48
	1976	1.75	0.75
	1980	1.13	0.46
	1984	1.05	0.40
Atlantic puffin (feeds on small fish)	1968	no data	0.89
	1972	2.57	0.76
	1976	1.27	0.59
	1980	1.03	0.55
	1984	0.74	0.30
Double-crested cormorant (feeds on larger fish)	1972	6.51	2.85
	1976	1.49	2.18
	1980	1.91	1.34
	1984	1.07	1.88

(a) Describe general differences between pesticide levels in birds' eggs from nesting sites around the Bay of Fundy and pesticide levels in birds eggs from nesting sites along the coastline of the Atlantic Ocean.

(b) Describe changes in pesticide levels from 1972, to 1984. What may account for the changes?

(c) Describe any differences in pesticide levels found in different species of seabirds. Suggest a reason for the differences.

What's Bugging You?

Although DDT is widely recognized as potentially hazardous, there are people who take issue with the ban on DDT. Why would this be so? One major concern is that a ban on DDT has serious health effects for the human population. In Zanzibar alone, the incidence of malaria dropped from 70 percent in 1958 to 5 percent in 1964 as a result of the application of DDT in that country. After the use of DDT was restricted, the incidence of malaria climbed upward, reaching 50–60 percent by 1984.

In attempts to find an acceptable substitute for DDT, the World Health Organization (WHO) screened approximately 2000 compounds for possible use as insecticides. Of the 30 compounds ultimately selected for field tests, none has proven as effective or as safe as DDT. Additionally, all of the substitutes are much more expensive to produce and deliver than DDT — an important factor for less developed countries.

To add to the problem, our attempts to produce safe and effective pesticides are hampered by the growing problem of pesticide resistance. Figure 3.6 illustrates the rise in the number of pest species that are resistant to the effects of pesticides in current use. This trend has implications for the future of pesticide use. The production of new pesticides, tests for safety and effectiveness, and the development of standards leading to guidelines for consumer use are all issues of critical importance in the future. The next activity will introduce you to more on this issue.

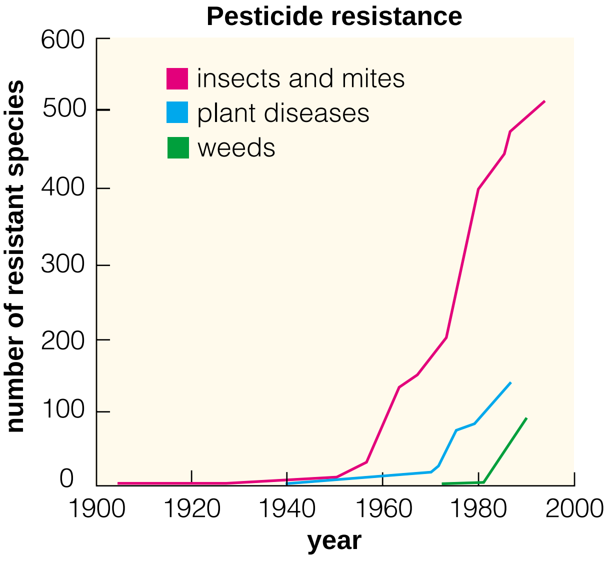


Figure 3.6 Growth in the number of pesticide-resistant species

Find Out **ACTIVITY**

The Use of Insecticides in Agriculture

Governments collect statistics on pesticide use to help develop and evaluate risk reduction programs. Such programs are then used to form the basis of government legislation and regulations. In this activity you will graph 1994 statistics comparing the use of insecticides in certain countries against the amount of agricultural land.

Materials

atlas of the world or access to the Internet

Country	Insecticide use (in Mt)	Agricultural area (in 1000 ha)
Canada	3 426	74 500
United States	103 419	420 250
France	8 848	30 119
India	41 994	181 030
Netherlands	439	1 971
United Kingdom	1 771	17 046

Procedure ✷ Performing and Recording

1. The table gives the total amount of insecticides used and the agricultural area in selected countries for the same year. Use the data to calculate insecticide use per 1000 ha of agricultural area and make a bar graph to represent your findings.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Which country has the lowest ratio of insecticide use to agricultural area? The highest ratio?

2. Insecticide use is dependent upon the type of crop. Typically cereal crops (wheat, barley, oats) require fewer insecticides than either fruit or vegetable crops. Using an atlas, or statistics from the Internet, determine the major agricultural crop type for each of the countries. Do your results agree with what would be expected?

Skill FOCUS

For tips on how to make bar graphs, turn to Skill Focus 10.

STRETCH Your Mind

Researchers from the University of Guelph reported in the April 1995 issue of the *Journal of Agriculture and Food Chemistry* that vegetables treated with pesticides could be healthier than pesticide-free vegetables. Potatoes naturally contain small amounts of the toxin solanine. Solanine is known to cause damage to the developing fetus in mammals. Under insect attack, potatoes produce greater amounts of solanine, perhaps as a chemical defence against pests. The researchers found that potato plants attacked by the Colorado potato beetle showed a 50 percent increase in toxin levels. In contrast, potato plants attacked by the potato leafhopper showed no significant change in toxin levels. The difference in the potato plants' reaction to attack is believed to be due to the feeding habits of the two insects. Can you guess what the difference in their feeding habits might be?

INTERNET CONNECT

www.mcgraw.ca/links/sciencefocus9

You have an insect "infestation" that you want to get rid of, but your neighbour is concerned about the insecticide you have chosen to use. What are your obligations to your neighbours from a legal and ethical perspective? Go to the web site above, and click on Web Links to find out where to go next. Then write a letter to your neighbour explaining your point of view and how you plan to make use of the information you have learned.

INVESTIGATION 3-C

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Organic Agriculture

Think About It

Canada is among the top five world producers of organic grains and oilseeds. Its organic agriculture sector is small but growing. Organic agriculture ideally uses natural processes and cycles to minimize environmental damage and optimize productivity.

In 1999 the Canadian General Standards Board published the *National Standard of Canada for Organic Agriculture*. This standard defines the guiding principles and regulations used to determine whether any product or operation can declare itself 100 percent "organic." In part, this act reads as follows:

"Operators of organic enterprises strive to reduce or eliminate reliance on practices using natural- or synthetic-based compounds that harm beneficial organisms within the soil, deplete non-renewable resources, compromise water and air quality, or which, through misuse, could endanger the health of agricultural workers, the agricultural community, or the consumer."

Canada's largest trading partner, the United States, has a similar set of guidelines in its 1990 Federal Organic Foods Production Act. In addition to outlining the rules and regulations governing the production and sale of organic products, this act includes a list of approved substances that may be used when circumstances warrant it. Interestingly, the list of approved substances includes pesticides derived from natural plants, microbes, insects, and mineral ores. In some special circumstances the use of synthetic pesticides may be approved.

Why is there a distinction made between organic and synthetic pesticides? Where do genetically modified organisms fit in the scheme of organic and synthetic pesticides? How can a naturally occurring mineral be used as a pesticide? What are the alternatives to the use of pesticides for controlling pests? How effective are those alternatives? In this investigation you will take a closer look at these questions.

How Can Science Help?

Our scientific knowledge has helped us develop synthetic pesticides and microbial pesticides, which contain micro-organisms. As well, we have learned to understand naturally occurring biochemical pesticides and the production of organic pesticides by plants after the addition of genetic material from another organism. The development and testing of new pesticides (regardless of type) require careful observation of the effects of a pesticide on all organisms, not just its intended target. The monitoring and critical analysis of any environmental effect allow scientists to weigh the benefits and risks associated with the possible use of that substance.

How does "organic" produce differ from produce grown by conventional methods?

What to Do

1. As a group, choose one of the following topics. Research your topic at your local library and/or the Internet. Prepare a one-page report summarizing your research.
   (a) What methods are used by organic farmers to control pest species (insects, weeds, fungi, bacteria) and to maintain soil fertility? How do these methods achieve the end result? How effective are these methods?

Under what circumstances should an organic farmer use an approved pesticide?

(b) As a group, brainstorm the characteristics that a safe, effective pesticide might have. Then determine the following information for the approved pesticides *pyrethrum*, *rotenone* and *neem*:
- **(ii)** source
- **(ii)** active ingredient
- **(iii)** effect on pest species, humans, and wildlife
- **(iv)** persistence in tissues and the environment

Do your criteria for safe and effective pesticides match the characteristics of those pesticides investigated?

(c) Determine the following information for the approved microbial pesticide *Bacillus thuringiensis*, commonly referred to as Bt.:
- **(i)** source
- **(ii)** active ingredient
- **(iii)** effect on pest species, humans, and wildlife
- **(iv)** persistence in tissues and the environment

What concerns would organic farmers have regarding a neighbouring operation planting crop plants genetically modified by the insertion of Bt. genes? What regulations exist in Canada for the use of genetically modified organisms in agriculture?

(d) As a group, brainstorm the characteristics that a safe, effective pesticide might have. Elemental sulfur, boron (as boric acid), copper (as copper sulfate), and potassium (as a salt of fatty acids or "soapsalt") are all approved organic pesticides. Determine the effect on pest species, humans, and wildlife; and persistence in tissues and the environment of these pesticides. Do your criteria for safe and effective pesticides match the characteristics of those pesticides investigated?

② Present a summary of your report to the class.

Skill FOCUS

For tips on how to use the Internet for research, turn to Skill Focus 9.

DidYouKnow?

You can limit your exposure to pesticides, antibiotics, moulds, and bacteria by taking a few simple precautions.

- Wash and scrub all fresh fruits and vegetables thoroughly under running water.
- Discard the outer leaves of leafy vegetables and peel fruits and vegetables.
- Cut the fat off meat or eat lower on the food chain to reduce your exposure to bioaccumulated chemicals.
- Handle and store food carefully to prevent contamination with other foods or moulds.

Analyze

1. A 1986 survey by Agriculture Canada found that farmers who chose organic methods did so because they felt organic methods were better for the health of their family and for the soil. Would the application of an organic pesticide change those expectations? Explain how the information you collected supports your answer.

2. Canada has been cited as ideal for organic agriculture due to its climate. Explain why climate might influence a country's suitability for organic agriculture.

Word CONNECT

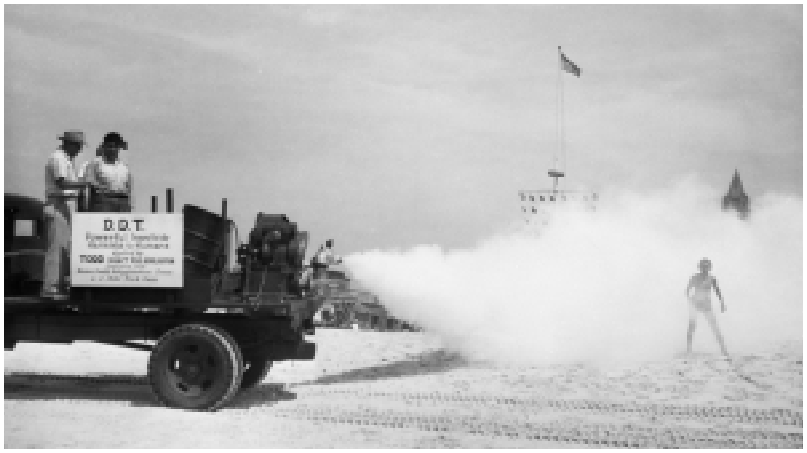
The term "poison" (from the Latin *potare*, "to drink") generally refers to chemical substances in our food that cause illness or death. The term "toxin" is usually reserved for protein molecules produced by a biological organism, and comes from the Latin *toxicum*, "a poisoned arrow." The Latin word *toxicum* can be traced back to the ancient Greek word *toxon*, referring to any bow and arrow. Is it correct to refer to industrial chemical pollutants as toxic waste? Look up the term "toxic" in a dictionary and check your answer.

Where to Now?

Whether it is derived from naturally occurring substances in the environment or is specifically formulated in a laboratory, the role of a pesticide is to control pests. Concern about the potential of pesticides to harm non-target organisms has led to a greater societal emphasis on the control and appropriate use of such substances. Research and development into new and safer pesticides has resulted in pesticides that break down faster in the environment. It is now recognized that natural processes and cycles can minimize the use of pesticides in our agricultural economies. Despite this, the fact remains that some pesticides and their breakdown products may remain in the environment for many years. Much of our knowledge of pesticides is on an individual basis and one of the challenges facing us in years to come is to determine the effects of combinations of these substances on the environment.

TOPIC 2 Review

1. What is a pest? What are pesticides?
2. There does not appear to be any concern about running through a cloud of DDT in this picture below taken at Jones Beach, New York, in 1948. In fact, many people were grateful that such trucks operated in their neighbourhood. Explain why this event could occur in 1948, but not in 1978.



3. What is the difference between toxic and poisonous?
4. Define organic farming in your own words. Is it a better method of growing food than conventional farming? Consider cost and practicality in your answer.
5. **Apply** List three ways you could reduce the use of pesticides in your home or yard.
6. **Thinking Critically** Why are pesticides harmful to birds at or near the top of the food chain?

TOPIC 3 How Do You Spell Relief?

Ahh! After a hard day mowing the lawn or raking leaves, there isn't anything better than the clean, refreshing taste of your favourite soft drink, accompanied by a big plate of sliced vegetables with a tangy blue cheese or sour cream dip, maybe even a peanut butter and jelly sandwich. As your aching muscles relax and you take another sip of that tart, cold drink, let your thoughts wander to the importance of acids and bases in your world.

You are already familiar with acids and bases in your environment — you experience them on a daily basis, as shown in Figure 3.7. The tart taste of carbonated beverages, the tang of a salad dressing, even the burning sensation in your muscles during exertion — all are due to **acidic** substances. The bitter taste of celery or radishes, the soothing action of a sunburn lotion, the slippery feel of soap — these are due to **basic** substances.

Figure 3.7 Some of the objects in this picture contain acids, while others contain bases.

Acids and Bases

Acids and **bases**, the chemicals that produce acidic and basic substances, have many uses in our lives. For example, phosphoric acid is a key component in the manufacture of fertilizers, detergents, and many pharmaceuticals. It is a flavouring agent in carbonated beverages, cheeses, jams, jellies — virtually any food with a tangy flavour.

Another important acid, sulfuric acid, is most familiar as the ingredient of the battery for your family's vehicle. But it is also used in the manufacture of paints and dyes, the refining of oil and gas, and the production of synthetic textiles. In fact, it is possible to get an approximate measure of any country's industrial activity by looking at the volume of sulfuric acid used by that country.

Of the basic substances, sodium hydroxide is a component of household and industrial cleaners, bleaching agents for the production of paper, fixatives in textile dying, solvents in the making of electronic circuit boards, and as a reagent in film processing. The base, aluminum hydroxide, is a key ingredient in antacid tablets. You may need this if you are going to mix peanut butter and jelly with blue cheese dressing!

The Observable Properties of Acids and Bases

As you can see, acids and bases are used for very different roles, so it is important to be able to identify acids and bases. You probably noticed that one of the first clues to whether a substance is acidic or basic is its taste. Acids taste sour (e.g., lemons) and bases taste bitter (e.g., horseradish). Unfortunately, tasting is not usually an acceptable option for laboratory work, so you can omit this method as a means of determining the basic or acidic nature of an unknown substance. Fortunately, acids and bases react differently with other substances, so we can devise tests to determine the acidic or basic nature of an unknown substance.

Likely you have experienced the slippery feel of soap (a basic substance). Although that property identifies basic substances, touching an unknown liquid with your bare hands is not a good idea in any lab setting.

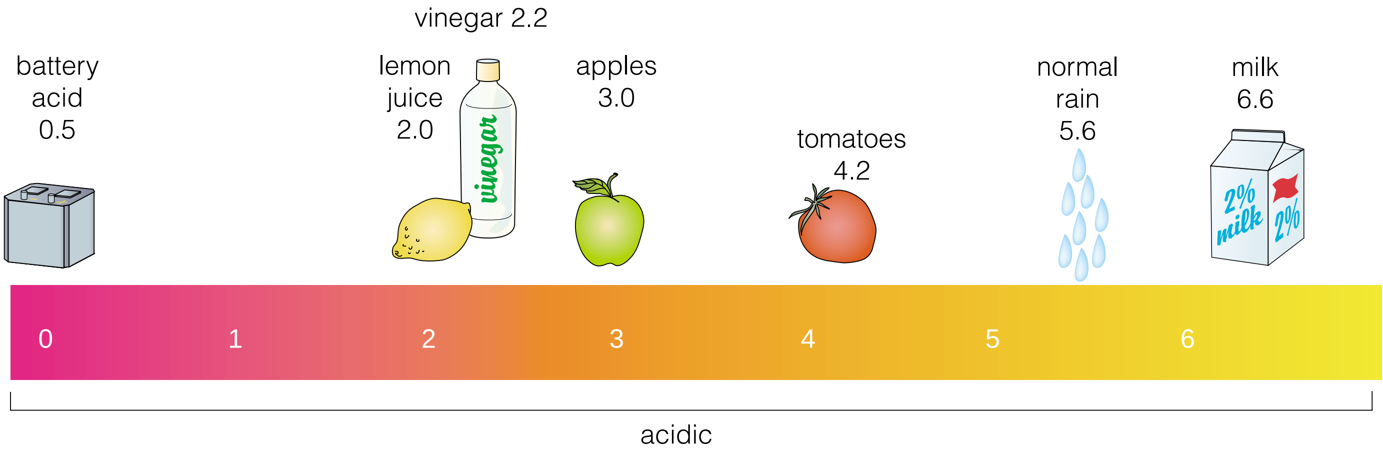
To safely tell whether a substance is an acid or a base, look for a noticeable colour change that occurs when an acid or base reacts with a chemical **indicator**. One of the best known indicators is **litmus**, a mixture of plant compounds extracted from certain lichens. This pinkish mixture turns red when in contact with an acid and blue when it contacts a base. Small strips of paper soaked in litmus are a standard diagnostic tool for chemistry.

Off the Wall

Some people like a wedge of lemon with their fish. Others prefer to sprinkle vinegar. Did you know that both of these are examples of neutralizing reactions? Fish contain a compound that is basic, so the acid in lemon juice or vinegar neutralizes the base. It may sound fishy, but it's true!

Stretch Your Mind

The "power" reported as pH is actually a power of ten in scientific notation. Take a strong acid, with pH 0.0, as a starting point. An acid with pH 1.0 has one tenth, or 10^{-1} times, the concentration. Vinegar, with pH 3.0, has only one thousandth, or 10^{-3} times, the concentration. How many times lower is the concentration of rainwater?



pH: A Powerful Scale

While litmus turns red in acid solutions and blue in basic solutions, it gives only an approximate idea of how acidic or basic a substance is. A more exact reading requires some technology.

The strength or concentration of an acid or base determines the extent to which it reacts with water. This reaction changes the electrical conductivity of the water, which can be measured with a sensitive meter, as shown in Figure 3.8. The **pH scale** is a way of comparing the relative acidity or alkalinity of a substance. In later courses, you will learn more about the criteria for measuring acidity and alkalinity and the exact chemical changes that occur when an acid or base reacts with water.

As shown in Figure 3.9, a pH of 7 indicates a solution that is neither acidic nor basic. It is neutral. If the pH of a substance registers below 7, the solution is acidic. Above 7, it is basic. There are a number of indicator substances that turn different colours depending on the pH of the solution. Universal indicator (containing many such indicators) or **pH paper** will change to a colour that is characteristic of a specific pH. These colours are then matched against a chart that shows the range of colours for known pH values.

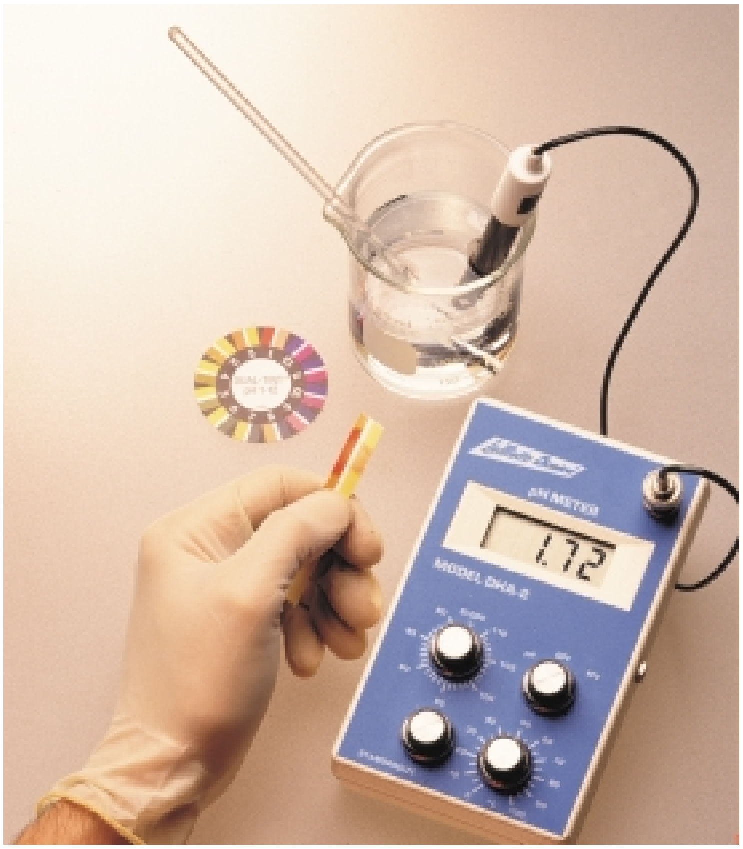


Figure 3.8 There are several ways to determine the pH of a substance. A pH meter and pH paper are two ways shown here.

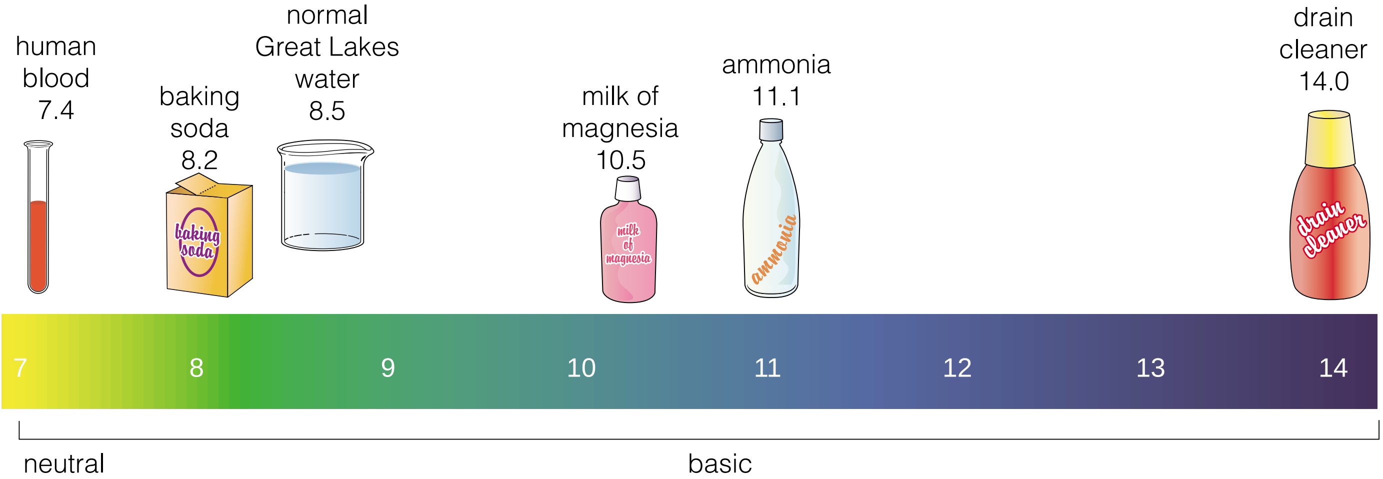


Figure 3.9 This diagram shows the pH of some common substances. Approximately how much more acidic is lemon juice than drain cleaner?

Find Out **ACTIVITY**

What Is the pH of Your Rain?

In this activity you will investigate the pH of some common acids and bases.

Materials

plastic container
rainwater (or melted snow)
pH paper, indicators, or pH meter

Procedure ✷ Performing and Recording

1. Decide which method you can use to test the pH of rain or snow.
2. During the next rainfall or snowfall, use the plastic container to collect a sample of the rainwater or snow. If you collect snow, let it melt.
3. Use an appropriate method to determine the pH of your sample.
4. Compare your results with your classmates' results.

What Did You Find Out? ✷ Analyzing and Interpreting

1. How did the pH value you obtained compare with your classmates' pH values? Account for any large discrepancies.
2. Calculate the average pH of the samples obtained by your class. Is this value what you might expect for your area? Why or why not?

DidYouKnow?

The word "pH" means the "power of hydrogen" and refers to the formation of hydrogen atoms that have lost an electron. Each pH unit on the pH scale stands for a tenfold increase in acidity or alkalinity. For example, a pH of 5.3 is ten times more acidic than a pH of 6.3, and a pH of 4.7 is 100 times more acidic than a pH of 6.7.

Word CONNECT

In Danish, the "p" of pH stands for *portenz* meaning "strength." In German, the word for "power" is *potenz*. Both of these words come from the Latin *potens*. Which words in English are related to the Latin word *potens*?

Some common acids and bases

INQUIRY

INVESTIGATION 3-D

SKILLCHECK

Initiating and Planning

✹ Performing and Recording

✹ Analyzing and Interpreting

Communication and Teamwork

The pH of Common Acids and Bases

Many common substances are either acidic or basic. In this investigation, you will make your own indicator and use it to find the pH of some common substances.

Question

What is the pH of a carbonated drink, and other common solutions?

Part 1

The Cabbage Test

Safety Precautions

- Ammonia is corrosive and toxic. Inform your teacher if you accidentally spill ammonia.
- If you spill any of the solution on your skin, immediately wash the area with cool water.

Apparatus

plastic container with a tight lid
potato masher, spoon, or fork
universal pH paper
test tubes and a test tube rack
100 mL beaker
glass stirring rod
medicine dropper
pH meter (for teacher use)
kettle (for teacher use)

Materials

2 red cabbage leaves

Solutions to Test (10 mL each)

lemon juice
vinegar
rainwater
distilled water
black coffee
liquid soap or shampoo
milk of magnesia
household ammonia
club soda (leave to last)

Procedure

1. Take two leaves from a red cabbage. Tear them into pieces about the size of a postage stamp. Put the pieces into a plastic container.

2. Ask your teacher to pour about 40 mL of hot water from a kettle into the container. Carefully seal the container, and leave it on your table to cool until it can be handled safely. While the water is cooling, complete step 3.

3. Copy the table below into your notebook. You will need enough space to **record** your observations for nine solutions. Also make a pH diagram similar to Figure 3.9. You will fill in substances as you determine their pH.

4. When the water in the container has cooled enough for you to handle the container safely, use the potato masher to mash its contents. Keep doing this until the liquid is deep blue or purple.

Solution	Colour of cabbage indicator	Approximate pH range
lemon juice		

CONTINUED ▶

⑤ Open the container, and carefully pour the liquid into a 100 mL beaker. Discard the cabbage leaves as directed by your teacher.

⑥ Pour about 10 mL of lemon juice into a test tube. Use a clean glass stirring rod to transfer a drop of the juice to a piece of universal indicator paper. Compare the colour with the colours in the chart. Estimate the pH of lemon juice, and **record** it in your table. Write "lemon juice" above the corresponding pH on your diagram. Rinse the stirring rod with water, and dry it with a paper towel.

⑦ Use the medicine dropper to add a few drops of cabbage juice indicator to the lemon juice. **Record** the colour of the indicator beneath the pH you estimated for the lemon juice.

⑧ Repeat steps 6 and 7 for each of the other solutions, except the club soda. About 20 mL of cabbage juice indicator should be left for step 9 and Part 2.

⑨ Pour about 10 mL of club soda into a test tube. Using only your observations of the colours of the cabbage juice indicator, estimate the pH of the club soda. Enter your observations for club soda in your table.

⑩ Set aside the cabbage juice indicator for Part 2. All other solutions can be rinsed down the sink with plenty of water. Discard indicator paper as directed. Wash your hands.

Teacher Demonstration

⑪ Although pH meters are more accurate than indicator paper, they are relatively expensive and require larger volumes of liquid. For these reasons, your teacher may demonstrate how a pH meter is used to measure the pH of the solutions you tested.

Part 2

Breath Check

You will use your indicator to analyze your breath. Does breath produce an acidic, basic, or neutral solution in water?

Safety Precautions

- If you spill any of the solution on your skin, wash the area immediately with cool water.

Apparatus

clean plastic straw
250 mL beaker
medicine dropper
stirring rod

Materials

cabbage juice indicator from Part 1
100 mL distilled water
5 mL household ammonia
20 mL vinegar

You can make your own indicator to test for acids and bases.

Procedure

① Pour about 100 mL of distilled water into the 250 mL beaker. Use the medicine dropper to add two drops of household ammonia to the water. Stir the solution. Rinse the medicine dropper with distilled water.

② Drop by drop, add just enough of the dilute ammonia solution from step 1 to the cabbage juice indicator to change the colour from deep blue or purple to pale green.

③ Using a clean plastic straw, carefully and gently blow a steady stream of bubbles through the indicator solution. Continue blowing until you **observe** a change. Remove, rinse, and discard the straw. Describe the change in your notebook.

④ Pour a little vinegar into the solution from step 2, until the colour changes. **Record** the new colour. Pour your solutions down the sink, and rinse with plenty of water. Wash your hands.

The straw is used to gently blow bubbles through the indicator. When finished, the student will rinse and discard the straw.

Analyze

1. List the solutions you tested from most acidic to most basic. Compare your list with the lists of other classmates.

Conclude and Apply

2. Which is more acidic, club soda, or a cola drink with a pH of about 3.0? Check the labels on containers for both drinks, and find an ingredient that might account for the difference.
3. Did the gas in exhaled breath dissolve in water to produce a solution that is acidic, basic, or neutral? Summarize the evidence that supports your conclusion. Which gas in exhaled breath caused the change?

STRETCH Your Mind

Since soils in different environments have different natural pH values, the plants that grow there have evolved to suit the pH ranges they must grow and live in. For example, rhododendrons flourish in moist, acidic environments and grow best at a pH of about 5. Many grasses, including wheat and maize, grow in drier environments, where they must tolerate a pH of 7 or 8. (What can you determine about the “natural” pH of rainwater from this?)

Gardeners and farmers can adjust the pH balance to suit the plants and crops they want to grow. Clay soils are harder to “fix” than sandy soils, for example. Lime (calcium carbonate) or dolomitic lime (which also contains magnesium carbonate) can be added to acidic soils, while ferrous sulfate or aluminum sulfate can help correct soil that is too alkaline.

Why do you think these substances can change the pH of a soil? Work out balanced chemical equations for reactions when (a) calcium carbonate is added to soil with excess nitric acid and (b) aluminum sulfate reacts with the water in an alkaline soil. Why are sodium hydroxide and sulfuric acid never used to adjust the pH of soil?

DidYouKnow?

Acid precipitation in one country can be caused by emissions from another country. In fact, more than 50 percent of the acid precipitation affecting eastern Canada is due to oxides originating in the United States. This has been an issue in political discussions between Canada and the United States since the 1970s.

DidYouKnow?

In 2001, David Schindler, an internationally recognized ecologist at the Univeristy of Alberta won one of the largest science prizes on the continent. His research on acid precipitation and the impact of phosphorus-based detergents on the world's freshwater supplies netted him the $1-million Gerhard Herzberg Canada Gold Medal for Science and Engineering.

Acid Precipitation—a Global Concern

Over the past 30 years, there have been few issues that have created more studies, debate, or controversy than acid precipitation. The chemistry behind acid precipitation is clear. Oxides of carbon, nitrogen, and sulfur produced by burning organic materials react with moisture in the air to form acids. The process is illustrated below.

$SO_{2(g)} + H_2O_{(\ell)} \rightarrow H_2SO_{3(aq)}$ **sulfurous acid**

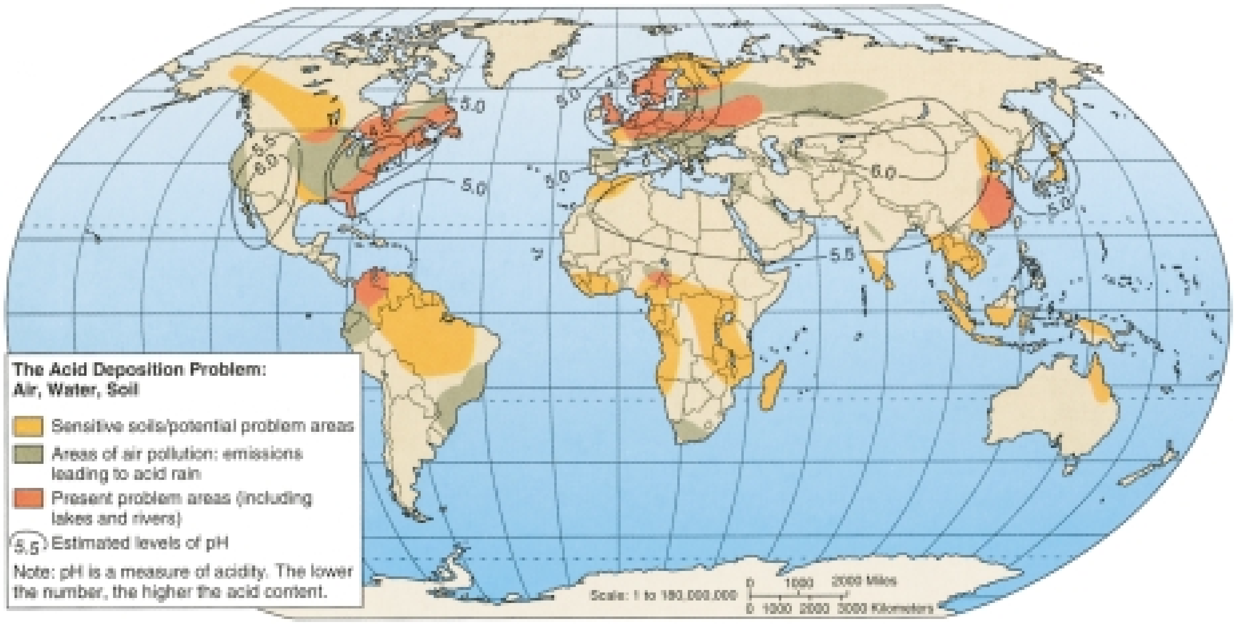
$SO_{3(g)} + H_2O_{(\ell)} \rightarrow H_2SO_{4(aq)}$ **sulfuric acid**

$2NO_{2(g)} + H_2O_{(\ell)} \rightarrow HNO_{2(aq)} + HNO_{3(aq)}$ **nitrous acid and nitric acid**

$CO_{2(g)} + H_2O_{(\ell)} \rightarrow H_2CO_{3(aq)}$ **carbonic acid**

In a process called **acid precipitation**, these acid compounds are washed out of the air by rain and snow and may be deposited a long way from the source of the oxides. Acid rain or snow looks, feels, and even tastes normal, but this rain or snow causes an estimated $1 billion in damage each year.

Acid damages and, in some cases, destroys aquatic ecosystems of lakes and streams, reduces productivity of crops, harms other vegetation, and accelerates the decay of our buildings, structures, and monuments. Acid corrosion is such a problem in Italy that some famous marble statues have had transparent cases filled with inert gases erected around them to prevent further damage. In Canada, the loss in productivity for agriculture, forestry, and fisheries means fewer jobs and lower profits. Corrosion and erosion of structural materials requires expensive maintenance and repairs to our buildings, bridges, and machinery.



The Acid Deposition Problem: Air, Water, Soil
Sensitive soils/potential problem areas
Areas of air pollution: emissions leading to acid rain
Present problem areas (including lakes and rivers)
5.5 Estimated levels of pH
Note: pH is a measure of acidity. The lower the number, the higher the acid content.
Scale: 1 to 180,000,000
0 1000 2000 Miles
0 1000 2000 3000 Kilometers
5.0
4.5
5.5
6.0

Figure 3.10 Sulfuric and nitric acids formed in the air by burning fossil fuels and other industrial activities threaten crops, water quality, building materials, and living organisms.

International Agreements

In 1996, in response to the public's concern about increasing damage to the environment, Canada and the United States agreed to reduce industrial exhaust emissions by 10 percent by the year 2000. In addition, exhaust emissions from cars built before 1998 were to be reduced by 60 percent. As a result of these pollution control measures, levels of sulfur and nitrogen oxides in the environment are diminishing.

There has been much disagreement over exactly how acid precipitation affects living organisms. After all, it looks, feels, and tastes normal. What is it about acid precipitation that causes damage? For terrestrial ecosystems, one major effect is that acid added to the soil dissolves mineral nutrients and allows them to be leached or washed away, resulting in nutrient-poor soil and poorer growing conditions for plants. In certain areas leaching may also free heavy metals to wash into streams and water supplies, where they may then be consumed by plants and animals. Heavy metals are those with a density of over 4.0 g/mL such as lead, mercury, cadmium, and nickel. These metals are deadly to most organisms. You will learn more about their effects in later Topics.

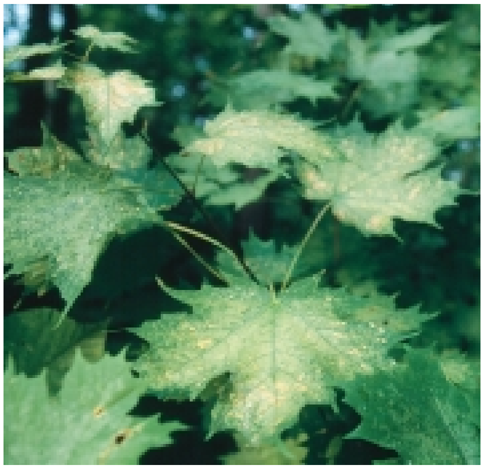


Figure 3.11 These maple leaves show damage by acid precipitation.

Career **CONNECT**

Toxic Substances Officer

Lori Forster-Clegg loved animals while growing up. She also loved biology. Lori brought those passions together with a diploma in biological sciences and pollution technology and then a Bachelor of Science in biology. During the summers she banded ducks, gathered information about spills, created pamphlets, and researched toxic substances. Now Lori is a toxic substances officer with Environment Canada's prairie and northern region — Alberta, Saskatchewan, Manitoba, Northwest Territories, and Nunavut — from her Edmonton office.

Lori's job involves being on the lookout for banned substances entering Canada, focussing mostly on ozone-depleting substances and substances new to Canada. Industries contact her to see if materials they want to import are regulated or illegal. New substances that aren't on the approved list need to be tested. The industry that is trying to import a substance conducts environmental and toxicity tests on the substance. They then submit these results to Environment Canada's headquarters in Ottawa. Lori helps industries put together their submission package and helps them understand the rules so they can more easily follow them.

Inspectors, ensuring that the environmental laws are being followed, also contact Lori about whether certain substances are banned. They look to her for answers and training. "I'm in a position to know the science behind the regulations — why they're in place — and how they benefit the environment," she says. Lori explains the environmental regulations so inspectors know what to look for when they are on-site. While she spends most of her time at her desk on her computer, inspectors often ask Lori to come along on calls because they are not familiar with the hundreds of different chemicals.

Does Lori's job sound interesting to you?

- Conduct some research over the Internet or at the library to find out more about what it takes to become a toxic substances officer.
- What level of education does it require?
- Which volunteer opportunities will give you experience in the field while you're still in school?

INQUIRY

INVESTIGATION 3-E

SKILLCHECK

Initiating and Planning

✹ Performing and Recording

✹ Analyzing and Interpreting

✹ Communication and Teamwork

The Effect of pH on a Population

In this investigation, you will examine the effects of acid precipitation by observing the effects of pH on the growth of a yeast culture.

Question

How do variations in pH affect the growth of yeast?

Safety Precautions

- Handle the hot plate with care to avoid burns.
- Handle the microscope slides with care.
- If you spill any of the solutions on your skin, wash the area with plenty of cool water.

Apparatus

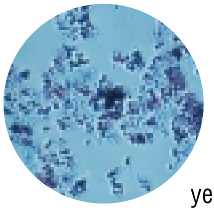
microscope
microscope slides
cover slips
100 mL graduated cylinder
7 test tubes
thermometer
100 mL beaker
hot plate
marker

Materials

yeast culture
water
dilute acid solution
dilute base solution
sugar
labels

Procedure

① Work in a small group. Measure 100 mL of water into the beaker. Place the beaker on the hot place, and bring the water temperature to 30°C. **CAUTION:** Handle the hot plate with care.



yeast cells

② Add 3 g of sugar and 0.5 g of yeast. Stir well.

③ Prepare seven test tubes with a pH range of 2 to 8. Label each test tube.

④ Add 10 mL of yeast culture to each test tube. Allow the test tubes to sit for 24 h.

⑤ Devise a sampling technique to estimate the relative population density of yeast in each test tube. Examine each sample under the microscope. **Record** your results.

⑥ Make a graph that shows the relationship between population density and pH.

⑦ Wash your hands after completing this investigation.

Analyze

1. At what pH did the yeast population show the most growth? At what pH did it show the least growth?

Conclude and Apply

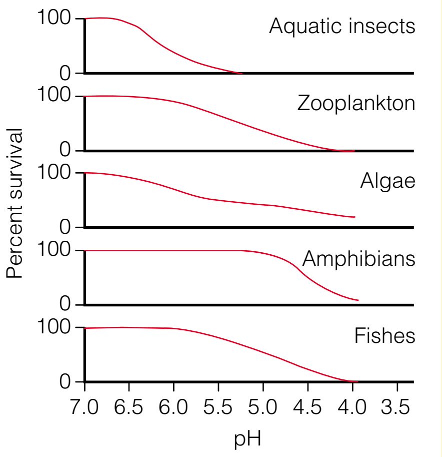
2. The graph shows changes in the populations of various aquatic organisms in Canadian lakes and rivers in relation to pH levels. Study the graph, and answer the questions.

   (a) Which organisms appear to be most sensitive to acid conditions? Which are least sensitive?

   (b) Why might the population of a species of fish that is tolerant of high acid levels still decline in an acidified lake?

   (c) "When fish start dying, the damage has already been done." From the information on the graph, explain why you agree or disagree with this statement. Which species might be better used as an early warning of acid damage in lakes?

3. From your results, and the data presented, make a general statement about the effects of acid precipitation on organisms.



Using Chemistry to Control Acid Effects

Acid precipitation falls all across Canada, but some areas are affected more than others. Believe it or not, the same chemical reaction that is destroying the marble tablet in Figure 3.12 is exactly the same reaction that protects areas of western Canada from acid precipitation. Study the chemical equation that accompanies Figure 3.12. Did you notice that the products of the reaction of calcium carbonate and sulfuric acid are not acidic?

During the last ice age (about 20 000 years ago), glaciers covered much of North America. As the glaciers advanced, they eroded the rocks over which they passed, carrying the debris with them. When the glaciers melted at the end of the ice age, the crushed rocks were left behind. In western Canada, the rock debris contained a substantial amount of alkaline minerals such as calcium carbonate or calcite. This calcium carbonate lying at the bottoms of lakes in the Canadian west neutralizes the acids entering these lakes.

This presents us with a chemical solution to the problem of acidified lakes. Add a quantity of powdered calcium carbonate to the lake in question and voilà — instant neutral water. One major source of calcium carbonate is limestone; the process of adding calcium carbonate to the environment is referred to as **liming**, as shown in Figure 3.13. The correct term for such a chemical reaction is an **acid-base neutralization**.

You might be wondering why we aren't neutralizing the effects of acid precipitation in all the acidified lakes if it is so easy. You will find out why after the next investigation.

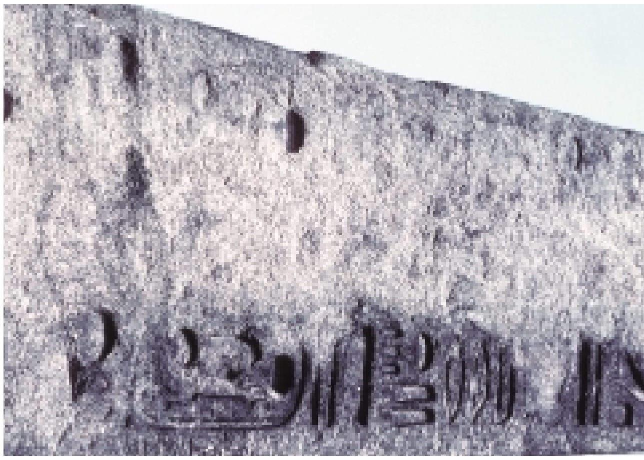


Figure 3.12 Many monuments and statues — some thousands of years old — are made of marble and limestone. These substances contain calcium carbonate ($CaCO_3$), which is easily decomposed by sulfuric acid:

$$CaCO_{3(s)} + H_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + H_2O_{(\ell)} + CO_{2(g)}$$

Calcium sulfate dissolves in water more readily than calcium carbonate. Thus the monuments and statues corrode as the calcium sulfate is washed away.

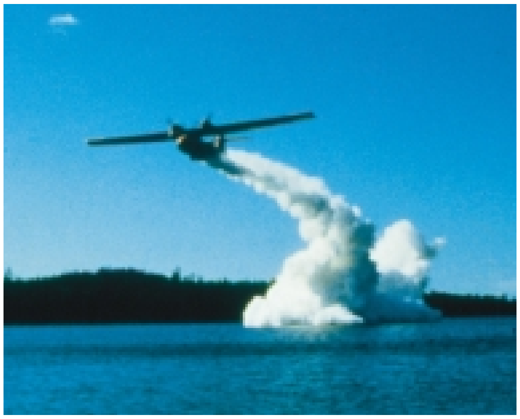


Figure 3.13 Liming is done by releasing powdered calcium carbonate from aircraft.

Off the Wall

Normal rainwater has a pH as low as 5.6 due to the carbonic acid formed as carbon dioxide gas dissolves into the water. The presence of sulfur oxides and nitrogen oxides from industry and transportation in the atmosphere results in rain that is even more acidic. Central Europe, Japan, and eastern North America are severely affected by acid precipitation. In these areas, rainwater can have an acidity approaching that of vinegar (pH 3.0), which is about 1000 times more acidic than normal rainwater. Amazingly, there are even more extreme acid conditions. In 1974 a storm dropped rain with a pH of 2.4 over Scotland, and fog over Los Angeles has been measured with a pH as low as 1.7! This is 10 000 times more acidic than normal.

INQUIRY

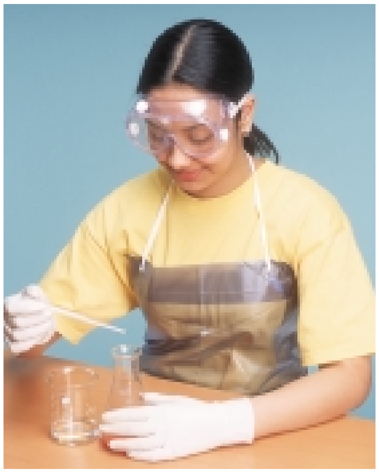
INVESTIGATION 3-F

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Drop-by-Drop Neutralization

As you know from Unit 2, when acids and bases neutralize each other, the products are water and a "salt" compound. Regardless of the strength of the acid or base, neutralization will occur, even though the amounts of acid and base may not be equal. A relatively weak acid or base can be used to neutralize spills of much stronger acid or base. An antacid is a good example. Acid in your stomach that helps digest your food has a pH of about 2. "Heartburn" occurs when acid from your stomach enters your esophagus. It is relieved by swallowing an antacid, which is just a weak base.



Question

How does an antacid compare with baking soda and a strong base in neutralizing an acid?

Prediction

Make a prediction about whether an antacid, baking soda, or a strong base will be most effective in neutralizing acid.

Safety Precautions

- This investigation uses caustic, corrosive substances. Clean up any spills carefully and inform your teacher.
- Bromothymol blue is flammable. Keep it well away from flames.

Apparatus

3 100 mL beakers or 3 petri dishes
2 medicine droppers or 1 mL micro-pipettes
stirring rod
balance

Materials

dropper bottle of bromothymol blue indicator
dilute sodium hydroxide, NaOH (aq)
dilute hydrochloric acid, HCl (aq)
(**Note:** These two solutions should have the same concentration)
water
antacid tablet
baking soda

Procedure

1. Place a few drops of bromothymol blue indicator in a small, clean beaker or petri dish. Then add 2 mL of sodium hydroxide solution.
2. While stirring the solution with the stirring rod, add hydrochloric acid slowly, counting the drops until the colour of the indicator just changes, and the colour change lasts at least 20 s. **Record** the number of drops and appearance of the solution.
3. Dissolve 2 g of baking soda into 2 mL of water. Repeat steps 1 and 2, using the baking soda solution in place of the sodium hydroxide solution.
4. Plan the steps you will take to compare the antacid tablet to the sodium hydroxide and baking soda solutions. (Hint: Break the tablet into pieces.)
5. Remove your gloves and wash your hands.

Analyze

1. Compare your results (the number of drops added in the three neutralization reactions) with your classmates' results. Discuss any differences.

2. Using the number of drops of hydrochloric acid needed to neutralize the antacid tablet and baking soda, calculate the mass of baking soda equal to one antacid tablet.

Conclude and Apply

3. What would happen if more baking soda were added after neutralization occurred? What colour would the indicator turn? Why?

4. What would be the danger in swallowing many antacid tablets?

5. Which base was most effective in neutralizing acid? How does the "alkalinity" of antacid compare to sodium hydroxide solution?

Using Chemistry to Control Harmful Emissions

You have observed how alkaline substances react with acids in a neutralizing reaction. So why not use this process to eliminate the problem of acidified lakes?

Liming has been used, but with limited success. Rivers and streams constantly feed acidified water into lakes, so the lakes would have to be limed continually to keep up with the new influx of acid. Imagine the cost of treating between 14 000 and 150 000 affected lakes! Do you think the cost would outweigh the benefits, or vice versa?

Since it is impractical and expensive to neutralize all of the acid precipitation we humans are causing, the only other option is to reduce or eliminate the oxides. How can this be done? Chemistry to the rescue!

Chemical engineers use their knowledge of chemistry to design and build devices to remove oxides *before* they get into the air. **Catalytic converters**, such as the one shown in Figure 3.14, are required on most vehicles and are a good first step.

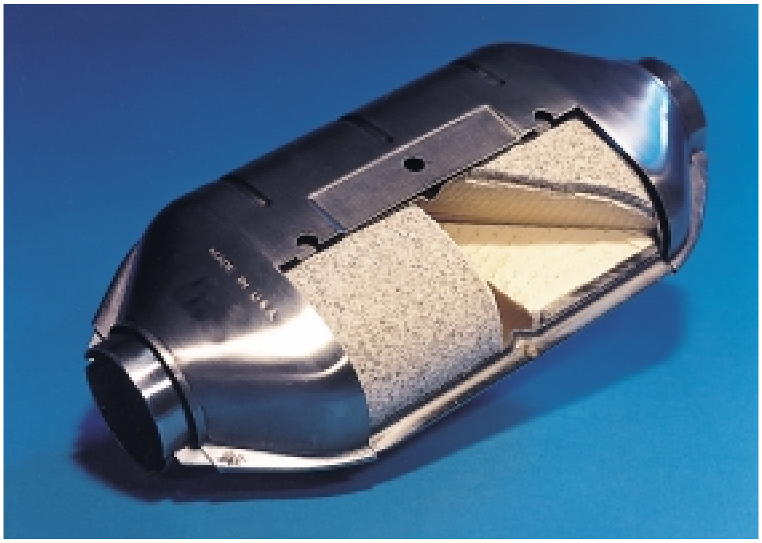


Figure 3.14 While catalytic converters are quite efficient, they work best when the catalysts are warmed up. It takes about 90 s, after a car starts, for the catalysts to be activated. Unfortunately, it is during this brief warm-up that the car produces about 70 percent of all the pollutants that it releases during its driving cycle.

DidYouKnow?

You might expect the pH of a lake to decrease gradually as acid water enters. However, this gradual decrease does not happen in a lake with a limestone bed. Such lakes are common in Southern Ontario, Southern Québec, and the Atlantic Provinces, but not on the Canadian Shield or the Prairies. Some lakes in the Rocky Mountains also have limestone beds. Calcium carbonate in the limestone bed of a lake reacts with acids, and so the pH stays fairly constant as acid water enters the lake. But when all of the limestone has reacted, the pH suddenly drops. The rapid change in pH is deadly to the ecology of this type of lake.

Catalytic converters contain a ceramic or wire honeycomb-like structure coated with a thin layer of metallic catalysts, such as platinum, rhodium, and palladium. A **catalyst** is a substance that speeds up a chemical reaction without being used up in the reaction. The large surface area of the honeycomb structure helps produce a complete combustion. A converter aids the formation of carbon dioxide and water from hydrocarbons, reducing the amounts of carbon monoxide and nitrogen oxides produced. The purpose of the converter is to encourage complete **oxidation**.

Word CONNECT

Look up the words "absorb" and "adsorb" in your dictionary. Explain the difference between them in your notebook.

Scrub Those Cares Away

The oxide emissions from industrial factories and power plants that burn coal can be a major source of oxides depending on the sulfur content of the coal being used. The installation of "**scrubbers**" (devices that use a **sorbent** — a substance that can adsorb, or capture oxides) is a good way to reduce oxide emissions.

Traditional "wet" scrubbers remove sulfur dioxide gas ($SO_{2(g)}$) by reacting heated gases with calcium oxide or lime (CaO). Figure 3.15 illustrates this process. The calcium oxide sorbent is used up in this reaction and the waste calcium sulfite ($CaSO_3$) is disposed of. A large power plant might produce millions of tonnes of waste calcium sulfite every year, most of which presently ends up in landfills.

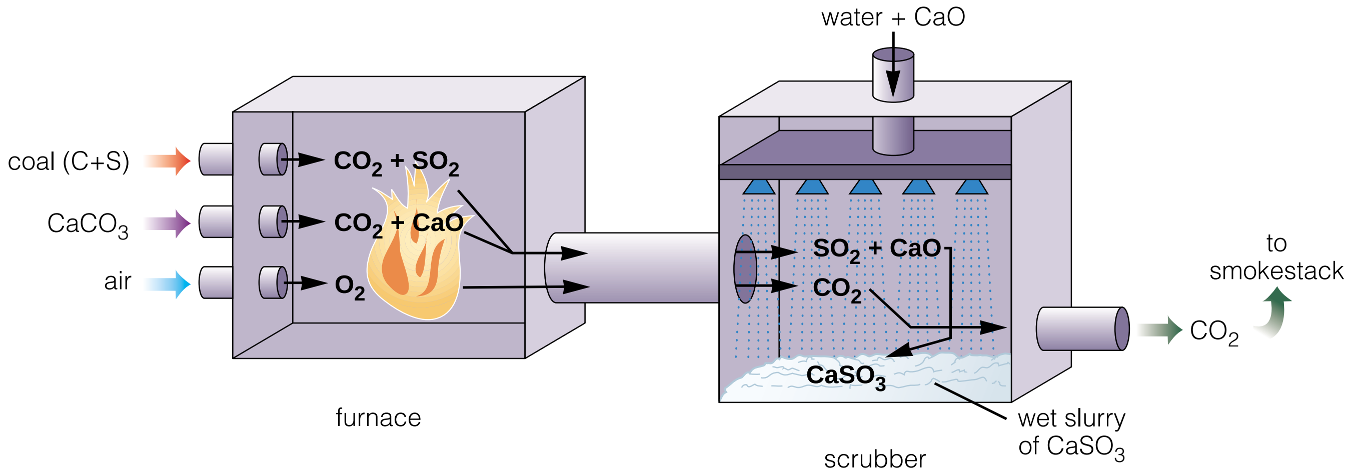


Figure 3.15 The key to "scrubbing" exhaust gases is the addition of calcium oxide (CaO), which reacts with the sulfur dioxide gas (SO_2) to form calcium sulfite ($CaSO_3$). The calcium sulfite can be washed away with water.

Figure 3.16 These little beads pack a big punch by removing sulfur dioxide and nitrogen oxides — pollutants responsible for acid precipitation — from gas given off during coal combustion.

Newer scrubber technologies have the potential to be more effective, environmentally friendly, and economical. The use of metal oxide sorbents (as shown in Figure 3.16) is the key. One such system, COBRA (copper oxide bed regenerable application), uses a sorbent of small beads of aluminum oxide impregnated with copper. The beads form clusters of copper oxide on their surface and as heated gases pass by, $SO_{2(g)}$ reacts with the copper oxide to form copper sulfate. Fresh beads are continuously added and "spent" beads are removed. The spent beads are then treated with methane gas to release the $SO_{2(g)}$ and restore the bead to its original state for reuse. Meanwhile the trapped $SO_{2(g)}$ can be treated to produce elemental sulfur, sulfuric acid, or even ammonium sulfate fertilizer.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

During the formation of coal, large amounts of methane-rich gas are created and remain trapped within coal beds and the surrounding rocks. Mining of coal beds will allow this methane to escape into the atmosphere where it acts as a potent greenhouse gas. Find out how "Clean Coal Technology" may turn this problem into a profit — both economic and environmental! Go to the web site above, and click on Web Links to find out where to go next. Design an advertising logo, jingle, or print ad to sell this new technology.

All of these products have applications we can make use of! As a bonus, the addition of ammonia to the heated gases triggers a catalytic reaction that breaks down nitrogen oxides into nitrogen and oxygen gas and water vapour.

In tests, COBRA removed all nitrogen oxides and 95 percent of the sulfur dioxide from emissions. This is comparable to or better than the results obtained by traditional scrubbers without the landfill waste. The copper oxide sorbent is more expensive to produce than sorbents in traditional scrubbers. However, since it is reusable, costs are recovered over time. As well, there is an end product to sell instead of waste to throw away.

Finally, what about the small amounts of oxide gases that make it past these devices? How much of a problem do they pose? What about the mountains of waste calcium sulfate produced by traditional scrubbers every year? Are they a problem? Both are pollutants, but how do they compare? You will explore this question in Topics 5 and 6.

TOPIC 3 Review

1. Which human activity is the major cause of acid precipitation?

2. Which key property do all indicators possess?

3. It is thought that pain results from a change in the pH of the fluid that surrounds nerve cells. The fluid within your cells is slightly acidic, so a cut or burn releases this fluid and causes pain signals from your nerve endings. What would you expect to find if you tested the pH of creams and lotions used to treat cuts and burns?

4. Suppose you have two containers, one containing a dilute acid and the other a dilute base, but there are no labels on them. Describe how you could use red cabbage to determine which solution is which.

5. Hydrofluoric acid, $HF_{(aq)}$, reacts with sodium hydroxide, $NaOH_{(aq)}$, to form a compound that is used in toothpaste to prevent cavities. What is the name of this compound?

6. **Apply** Coffee makers and kettles eventually become clogged with a buildup of "scale" from deposits of calcium carbonate and magnesium carbonate. Explain how pouring vinegar into your coffee maker or kettle removes this scale.

7. **Thinking Critically** Give three reasons why eastern Canada is more affected by acid precipitation than western Canada. How might increased acidity levels affect the economy of eastern Canada? Consider tourism, factories, and taxes.

DidYouKnow?

Fossil fuels such as coal, oil or natural gas are the sedimentary remains of swamp vegetation. Burning fossil fuels releases solar energy, which was stored in plant matter through the process of photosynthesis millions of years ago. Intense heat and pressure exerted on the plant matter initially forms bituminous (soft) coal. Higher pressures and temperature change bituminous coal to the harder anthracite coal. Alberta contains 70 percent of Canada's coal reserves, mostly of the sub-bituminous category. Approximately four-fifths of the coal produced in Alberta is used as fuel for the generation of electricity. Alberta coal is low in sulfur and burns cleaner than most coal found in other areas of the world.

Wrap-up TOPICS 1-3

If you need to check an item, Topic numbers are provided below.

Key Terms

nutrient
macromineral
trace element
enzyme
vitamin
protein
lipid
carbohydrate
biological magnification
biomagnification
herbicide
insecticide
fungicide
pesticide
acidic
basic
acid
base
acid precipitation
indicator
litmus
oxidation
pH scale
pH paper
acid-base neutralization
leach
heavy metal
liming
catalyst
catalytic converter
scrubber

Reviewing Key Terms

1. In your notebook, write the description in column A beside the correct term in column B.

A	B
• a naturally occurring catalyst found in cells	• pH scale (3)
• the reaction of an acid and base to form a salt and water	• trace element (1)
• process where chemicals collect in the tissues of organisms, increasing in concentration toward the top of a food chain	• acid precipitation (3)
• a chemical substance that changes colour in response to changes in acidity or alkalinity	• enzyme (1)
• a mineral needed in amounts less than 100 mg per day	• catalyst (3)
• a substance that speeds up a chemical reaction but is not depleted or changed by the reaction	• biological magnification (2)
• a scale that measures the relative acidity or alkalinity of a substance	• acid-base neutralization (3)
• rain or snow that contains high levels of acid	• poison (2)
• a substance that causes illness or death when it enters the body in food or drink	• indicator (3)

Understanding Key Concepts

2. Modern food processing and refining used in the packaging of food products decreases the magnesium and potassium contained in those foods. Name some of the likely symptoms shown by a person eating only refined foods. (1)

3. What is the role of an enzyme in your body? (1)

4. What are the characteristics of DDT (and other "chlorinated" hydrocarbon pesticides) that make it both a valuable pesticide and an environmental problem? (2)

5. The figure below shows a field planted with hybrid wheat called triticale. It is richer in protein than wheat and is used for human food and livestock feed. List two risks and two benefits of planting only one crop, such as triticale. (2)

6. List the characteristic properties of acids and bases. (3)

7. Your brother has eaten too many doughnuts, and now he has acid indigestion. He cannot find a commercial antacid product. Could he use baking soda? Explain why or why not. (3)

TOPIC 4 How Much Is Too Much?

Figure 3.17 This lake in the Canadian Rockies is a renewable source of fresh water.

Water is an essential ingredient for living organisms, and Canada is fortunate to have vast supplies of it. Some countries, such as Kuwait or Bahrain, have no renewable fresh-water supplies. How much of a shock is it then, to find that most authorities would recommend against drinking the water directly from the lake shown in Figure 3.17? To be safe, you need to filter or boil the water at least five minutes to remove the parasite, Giardia, which can cause the intestinal illness, commonly known as beaver fever. Would you agree that the water in such a lake is polluted? Could you tell just by looking?

In some cases it might be obvious that pollution is present; in others it is not so obvious. So, when can we be sure that a body of water is polluted?

To answer this question, you first need to know the difference between pollution and a pollutant. In general, a **pollutant** is any material, or form of energy, that will cause harm to a living organism. The harm may be the result of physical, chemical, or even biological mechanisms that threaten the health or survival of that organism.

Pollution is any alteration of the environment producing a condition that is harmful to living things. For example, you have read about the effects of the pesticide DDT. That is a case of pollution. The harm may not be immediate, but it does occur; the only question is when.

At what point does the concentration of a pollutant become a problem? Does it happen when the pollutant causes the immediate death of an organism? When the pollutant is only somewhat harmful? Perhaps when the pollutant is present at a level that you can detect? The next investigation will give you an appreciation for how difficult a question this can be to answer.

INQUIRY

INVESTIGATION 3-G

SKILLCHECK

✹ Initiating and Planning
✹ Performing and Recording
Analyzing and Interpreting
✹ Communication and Teamwork

Where Does Pollution Begin?

Chemicals are all around you. The water you drink, the foods you eat, the air you breathe — are all chemicals. Of the thousands of chemicals in use, some are human-made and some are natural. Some are harmless, and some are hazardous. Others are of unknown toxicity, either because they have not been tested or they are difficult to detect. The amount, or dose, of a chemical determines how much harm will be caused, so it is important to be able to detect the presence of chemicals. Unfortunately, the only way to determine the level of a hazardous chemical is to observe its effect on a living organism. To complicate matters, different organisms respond differently to the same dose of a chemical. To find out how dangerous a chemical can be, you must find out what its effects are—it must be tested on a living thing.

Question

How much of a chemical needs to be present in order to be detectable?

Safety Precautions

- Do not use laboratory glassware. It may look clean, but is it? Obtain plastic drinking glasses and carry out this activity only in a classroom, or in a cafeteria.
- It is not usually recommended to taste anything during experiments however, this investigation includes a safe tasting situation.

Apparatus

8 clean plastic drinking glasses of the same size and shape
3 clean plastic drinking glasses of any size or shape
marking pen
spoon
ruler

Materials

5 mL of salt
tap water
5 mL of sugar

Part 1

Preparing Serial Dilutions

Procedure

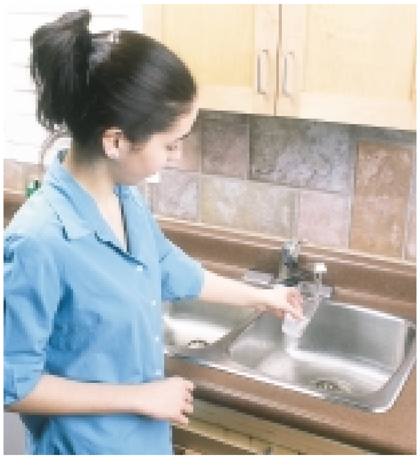
① Make a mark near the top of one of the glasses using the marking pen. This glass will become your standard glass. The mark on the glass will help you fill the glass with the same amount of water each time.

② Use the marker to label the remaining glasses from 1 to 7

③ Put 5 mL of salt into the standard glass and fill the glass to the mark with warm tap water. Stir until the salt dissolves.

④ Pour the salt solution from your standard glass into the glass labelled number 1. Using a ruler, **measure** from the top of the solution to the bottom of the glass. Use the marker to place a mark on the glass that is one-tenth of the way down from the top of the solution.

⑤ Carefully pour off the top one-tenth of the salt solution from glass number 1 (that is, down to the mark) and put it into your standard glass. Place glass number 1 aside for later testing.



⑥ Add warm tap water to the standard glass to fill it back to the original mark and stir.

⑦ Pour the diluted salt solution from your standard glass into glass number 2. Again, **measure** and mark a spot one-tenth of the way down from the top of the solution to the bottom of the glass. Carefully pour off one-tenth of the salt solution from glass 2 and put it back into your standard glass. Place the glass aside for later testing.

⑧ Repeat steps 6 and 7 with glasses numbered 3 to 7 to produce weaker and weaker dilutions of salt solution.

Part 2

The Taste Test

Procedure

① Use the three clean, unmarked glasses. The person tasting (the test subject) should have no knowledge of which glass contains the salt solution. This is called a "blind" test.

② Away from the view of the test subject, pour a little of the salt solution from glass number 7 into one of the unmarked glasses. Fill the other two with tap water.

③ Ask the test subject to taste the water in each of the three glasses and try to identify which has the salt solution in it. **Record** the accuracy of this guess.

④ Repeat steps 2 and 3 with each of the remaining numbered glasses, working backward from glass number 6 to glass number 1.

Part 3

How Sweet It Is!

Procedure

① Rinse all of the equipment you have used. Repeat Parts 1 and 2 of the procedure, substituting sugar for salt.

Analyze

1. Glass number 2 contained a salt (or sugar) solution that is approximately one-tenth as salty (or sugary) as glass number 1. In other words the solution in glass 1 is about ten times more concentrated than the solution in glass 2. Approximately how many times more concentrated is the solution in glass 1 than in glass 7?

2. At what dilution (in which glass) could your test subject taste the salt? The sugar? Compare your results with the results from other groups. Did other groups obtain similar results?

Conclude and Apply

3. Explain why there might be a difference in the results you obtained using salt and sugar. Was there a difference in results between people? What do you think would cause this discrepancy?

4. The purpose of a "blind" study is to ensure that your results are less likely to be influenced by bias. What do you think a "double blind" study is? Why would such a study be used?

How Much Is That?

In the previous investigation you used 5 mL of salt or sugar in a glass of water. After one dilution, you obtained a salt or sugar concentration that was one-tenth of the original, or 10 percent. Your serial dilutions produced concentrations of hundredths (1 percent), thousandths (0.1 percent), ten thousandths (0.01 percent), and so on.

For many of the products that you use or buy, the standard way of indicating *how much* of a substance is present is to refer to the percentage (%) of weight or volume it represents.

Yogurt is a good example. When the label states 1 percent milk fat, it means that 1000 g of yogurt contains 10 g of milk fat. Or, to put this in a simpler ratio, 1 g of milk fat is mixed into 100 g of the other substances that make up yogurt. In fact, the term "percent" actually means parts per hundred. In your studies you will already have encountered the unit parts per million (ppm), and even units of parts per billion (ppb). The iodized table salt that you probably used in your investigation contains about 76 g of potassium iodide (KI) for every 1 000 000 g of sodium chloride (NaCl) for a concentration of 76 ppm potassium iodide. Did you notice that you were able to taste the iodine in the diluted salt solutions in the last activity before you were able to taste the salt?

It is hard to imagine such small amounts of a substance as being detectable, never mind harmful, but in fact you will see even smaller amounts being considered. The element cadmium is considered toxic when it reaches concentrations of 17 parts per trillion (ppt)! To picture one part per trillion, imagine one quarter in a stack of quarters 2000 km high.

Figure 3.18 Read the nutrition information on the label to find out the percent milk fat of the yogurt you eat.

Example:

If the nutritional information label on a container of yogurt specifies that each 125 g serving contains 7 mg of cholesterol, what is the concentration of cholesterol in a serving of yogurt in parts per million (ppm)?

Solution:

First, state your information as a ratio.

$$\frac{7 \text{ mg cholesterol}}{125 \text{ g yogurt}} = 0.056 \text{ mg/g}$$

Second, express that ratio in the form of mg/kg

$$0.056 \text{ mg/g} \times 1000 \text{ g/kg} = 56 \text{ mg/kg}$$

Since mg/kg is equivalent to ppm, there are 56 ppm of cholesterol in each serving of this yogurt.

The Danger Is in the Dose

Toxicity is the ability of a chemical to cause harm to an organism. The harm can either occur directly or be caused by the substances that form in the organism as it uses that chemical. A chemical has **acute toxicity** when serious symptoms occur after only one exposure to the chemical. Methyl isocyanate is one such chemical. **Chronic toxicity** is diagnosed when symptoms appear only after a chemical accumulates to a specific level after many exposures over time. Lead is an example of this type of substance. For both acute and chronic toxicity, exposure to a chemical is critical. Regardless of how the damage occurs, or even why it occurs, it is the amount of the chemical causing that damage that matters. Unfortunately, it is not always easy to establish the level at which a substance is toxic. Due to differences in body mass, metabolism, and even lifestyles, different organisms will vary in their response to a particular toxin.

Word CONNECT

The word "pollution" comes from the Latin *pollutus*, which means "made unclean, foul, or dirty." Look up the term "pollution" in a thesaurus and list as many synonyms for pollution as you can find.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

How critical is the state of our water supplies? What solutions can we come up with for the problem of polluted water sources? Go to the web site above, and click on Web Links to find out where to go next. Write the answers to these questions in your notebook.

DidYouKnow?

Some of the minerals you take into your body could be harmful rather than helpful. Intake of "heavy metal" ions such as mercury and lead may cause death of nerve cells, which results in permanent neurological damage. The Government of Canada has established guidelines for acceptable amounts of such metals in our fresh-water supplies. This table shows some of those limits.

Mineral pollutant	Maximum permitted level (in ppb)
arsenic	5.0
barium	1000.0
cadmium	0.017
chromium (trivalent)	8.9
chromium (hexavalent)	1.0
lead	7.0
mercury	0.1
selenium	1.0
silver	0.1

DidYouKnow?

Strawberry crops are severely damaged by cyclamen mites. Attempts to control cyclamen mites with the insecticide parathion failed drastically. In one study, a cyclamen mite population increased as much as 35 times after the application of parathion. Upon investigation, it was found that another mite species, one that normally preyed on cyclamen mites, was even more sensitive to parathion. With the predator species wiped out by the parathion, the surviving cyclamen mites were able to reproduce and grow without being eaten by their normal predator.

Lethal Dose 50

Table 3.4

LD50s for Various Chemicals

Toxin name	Source	Approximate LD50s (in ppm)
botulinum toxin A	*Clostridium botulinum* bacterium	0.00000003
tetanus toxin A	*Clostridium tetani* bacterium	0.000005
dioxin	contaminant in some herbicides and in PCBs	0.03
nicotine	cigarette smoke	0.86
strychnine	pesticide	5.0
solanine	potatoes	6.0
chlordane	insecticide	40.0
dieldren	insecticide	80.0

A common measurement of the toxicity of a substance is by its Lethal Dose 50. **LD50** refers to the dose of a chemical that will kill 50 percent of the population to which it is applied. The LD50 for a chemical takes into account that some individuals within the target population may be more resistant to the toxic effects of the chemical. Table 3.4 summarizes just a few of the LD50s that have been established for the human population. Each LD50 in the table is expressed in parts per million within the human body. An LD50 does not refer to parts per million in the environment or in materials ingested by humans.

The most lethal poison known arises from the bacterium, *Clostridium botulinum*. This bacterium is common in foods and can be destroyed by high temperature and acidity. Other bacteria species produce toxins that are almost as lethal. In fact, you may have noticed in reading Table 3.4 that the toxins produced by bacteria are much more lethal than dioxin, the most deadly of the human-made toxins.

The LD50 of a chemical is only a useful guide to how we should handle that substance. For example, a chemical with LD50 of 15 ppt is one for which proper safety precautions should be followed.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To find out more about how toxic substances affect us. Go to the web site above, and click on Web Links to find out where to go next. Choose three substances, and describe their effects in your notebook.

Word CONNECT

Preserved foods that have not been exposed to sufficiently high temperatures in the preservation process are often the source of the fatal illness "botulism." The name comes from *botulus*, the Latin word for sausage. The origin of this weird "link" originates with an outbreak of the illness in nineteenth-century Germany. Contaminated sausages were identified as the culprit, so the disease became known as botulism. When the bacterial culprit was eventually isolated and identified, it was named *Clostridium botulinum*. Which other English words have their origin in the Latin word *botulus*?

An Acceptable Risk?

Government agencies and legislative bodies are often pressured to relax the strict testing required before a new drug or substance is approved for everyday use. Many people view the waiting period as inconvenient and unnecessary. However, there are good reasons why these waiting periods are in place. What do you think they are?

Since not all individuals or species react the same to a particular chemical, establishing risk is often difficult. First, a dose that kills one individual may cause only mild discomfort in another. Second, the toxicity of a chemical often depends on how the chemical enters the body. Inhaling or ingesting a chemical is much more likely to cause harm than spilling the same chemical on your skin. Third, you can't completely rely on published toxicity values to determine the effects on humans, because few actual measurements have been made. Most of the information regarding humans is the result of studying accidental-exposure cases. Why would that be? Would *you* volunteer to be a test subject for a toxicity experiment? Another reason to question the reliability of toxicity values is that they are merely guesses based on the assumption that humans will react to a chemical in the same way that a laboratory rat or mouse will. So despite the best efforts of scientists, sometimes a substance will be approved for use with tragic effect.

Thalidomide Issue

The drug thalidomide is an example of just such a tragic effect. Originally developed as a sleeping pill, thalidomide was subjected to the usual toxicity tests and declared harmless. Its use by pregnant women in the 1950s and 1960s resulted in the birth of thousands of babies with absent or extremely shortened limbs. After the first birth deformities were noticed, further testing established that lab rats can take doses of thalidomide as high as 4000 ppm with no ill effect, but pregnant women who received a much smaller dose (0.5 ppm) at just the wrong time during pregnancy, produced a child with missing limbs, as shown in Figure 3.19.

Figure 3.19 In light of the fact that thalidomide is one of the most effective drugs doctors have for the treatment of many diseases, such as lupus and rheumatoid arthritis, should it be struck from the list of approved drugs?

Figure 3.20 Saccharin is a sugar substitute that is 500 times sweeter than sugar. It was first discovered in 1879 and used commercially by 1907. Now it is a controlled substance, since it has been found to produce cancerous effects in some lab animals. While saccharin is still an accepted food additive, it is required that foods containing saccharin be labelled as possibly hazardous to your health. Saccharin generates an almost undetectable risk of cancer in humans.

The Evaluation of Risk

There are often articles in the newspaper relating to toxic spills of chemicals, or concerns about pesticide use. Rachel Carson's *Silent Spring* was a rallying cry for the environmental movement in the 1960s and forced a re-evaluation of how much humans influence the environment.

With all of the publicity surrounding the human use and abuse of toxic chemicals, we sometimes overlook the fact that most of these poisons are natural, not human-made. The chemical defences that plants and animals have evolved to discourage predators and eliminate competitors are in general much more toxic and numerous than synthetic toxins. For every molecule of human-made pesticide in our diet that is a result of agricultural use, there are as many as 10 000 molecules of naturally formed pesticides — some almost identical in structure and function to human-made ones. So how do you calculate the risk involved in our use of pesticides? What is a safe level for any pesticide?

We take risks every day in all kinds of activities. More importantly, we accept those risks as normal. The risk of spraining your ankle does not prevent you from walking down the sidewalk. Perhaps it is better to talk about "acceptable risk" when evaluating the safety of an activity. For example, a cup of coffee contains the alkaloid chemical caffeine, a nervous system toxin that has an LD50 for mice of 130 ppm. Does that make it dangerous for humans? Consider this:

- Humans would have to drink 70 cups at one sitting to get a dose equivalent to the LD50 for mice.
- It may not be accurate to use the established dose for mice to calculate the dose for humans. If thalidomide can have different harmful dose levels for humans than for rats, perhaps caffeine has different dose levels for humans than for mice.

The risk is there, but obviously not much of one. For many people, drinking coffee is an acceptable risk.

Benefits Versus Drawbacks

Every chemical has the potential to be harmful, depending on dose, our susceptibility, and how it reacts with other chemicals. We must decide if its use is more beneficial than harmful. Is it better to treat crops with fungicides known to have cancer-causing properties or to allow moulds to grow, many of which are far more likely to cause cancers? Is the risk from agricultural pesticide residues less than the risk from the natural toxins a plant produces when attacked by insects? The evaluation of the risks and benefits of any chemical form the basis of how chemical use is regulated. Of course, a proper analysis for potential risks and benefits requires an understanding of which chemicals are present. How can we do that? The next Topic will introduce you to some of the methods.

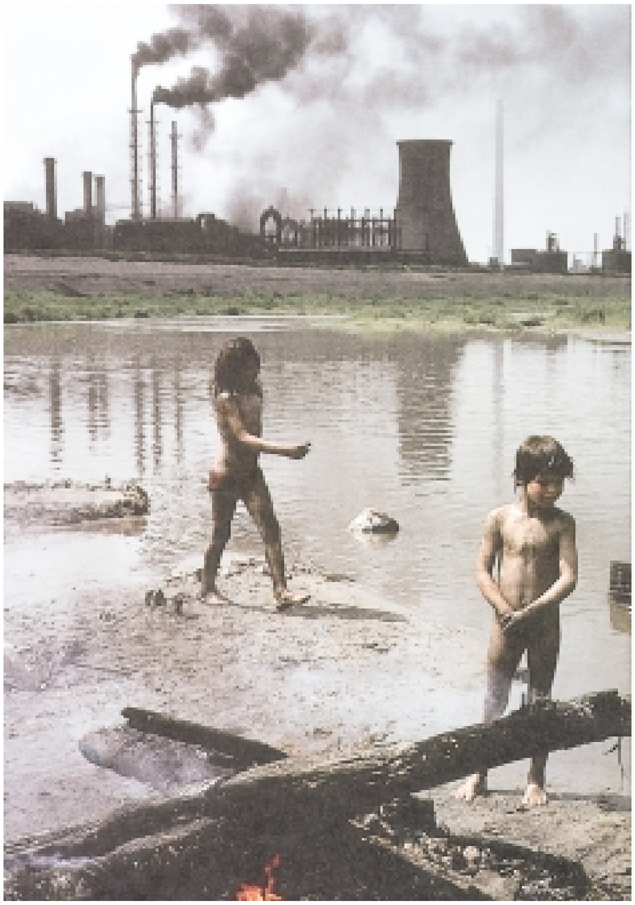
TOPIC 4 Review

1. What is the difference between a pollutant and pollution?

2. What is the difference between acute and chronic toxicity?

3. The maximum permitted level of mercury in our water supplies is 0.10 ppb. A scientist determines that a water source has 0.20 mg of mercury per litre of water. Would this water supply be considered unsafe? Explain your answer.

4. **Thinking Critically** The photograph below shows two children, playing in a river across from a factory that produces a carbon "snowfall," which turns everything in the area black. Would you consider the water to be polluted? What reason would you give for saying so? How could you determine if it actually is polluted?



DidYouKnow?

Some toxins can make the skin so sensitive to sunlight that even moderate amounts of sunlight can cause sunburn-like symptoms. Upon recovery, the skin is often permanently darkened. Many pesticides and plants are known to cause this sensitivity to sunlight — the carrot is one such plant.

5. Explain the term LD50 in your own words. Why is an LD50 a more accurate way of reporting the effects of a chemical than just the toxic dose that an individual has taken in?

6. Think back to the Inquiry Investigation at the beginning of this Topic. Which glass containing salt water would you consider to be polluted? Why? Check with your classmates. Did they agree with your choice?

TOPIC 5

Getting Away from It All?

How far do you think you would have to travel to "get away from it all" to a place remote from the noise, crowding, and debris associated with our growing human population? The answer is, surprisingly far.

Every organism that exists, or has existed, exploits the environment to the best of its ability. Regardless of the type of organism, materials and energy are taken from the environment, and waste products are deposited. Usually wastes are used by other organisms as resources, so overall the environment remains relatively balanced over time. However, this is the case only if the rate at which wastes are removed is equal to or greater than the rate at which those wastes are produced.

Like other organisms, humans exploit their environment and then produce wastes in proportion to that exploitation. In the past when the human population was much smaller, this was not a problem — the environment could handle the amount of waste we produced. In the early 1800s there were about 1 billion humans on Earth, but this doubled by 1930. It doubled again by 1975 and reached the 6 billion mark by late 1999. How much of the world's resources does it take to support 6 billion humans? How much waste do 6 billion humans generate? How is it possible to measure this?

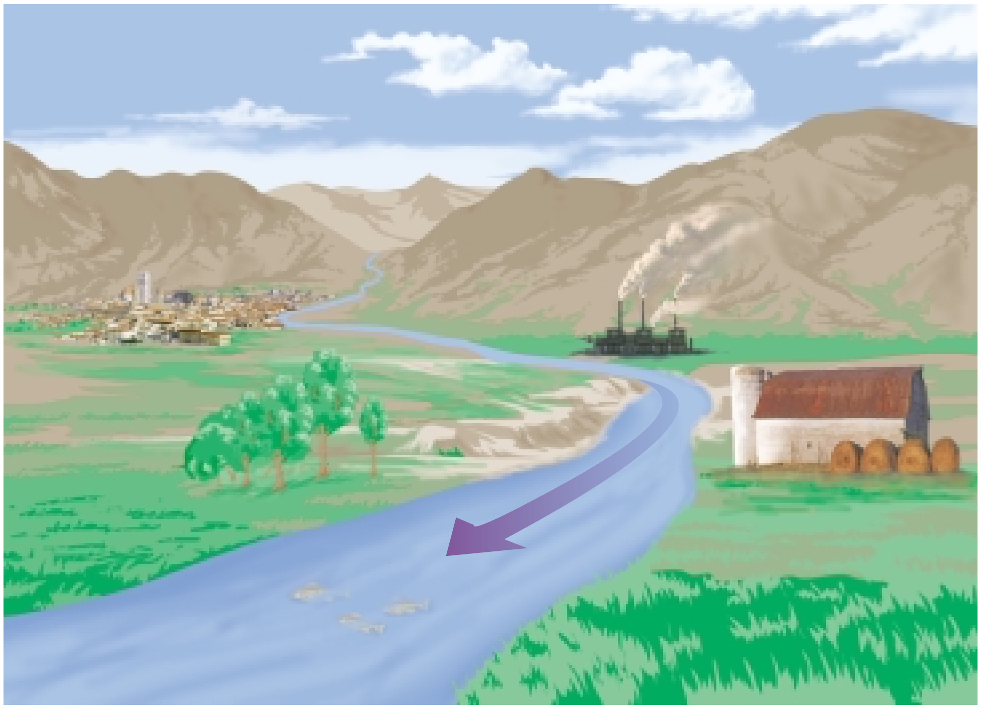


Figure 3.21 Where would pollutants most likely enter this river? What kind of pollutants do you think they would be?

Environmental Monitoring

All wastes entering the environment are potentially harmful, but some more so than others. Wastes that can be broken down into simple non-polluting compounds by naturally occurring chemical reactions, or bacterial action, are referred to as **non-persistent**. Fertilizers and sewage are examples of this type of pollutant. On the other hand, **persistent** pollutants accumulate in the environment, break down very slowly, or perhaps not at all. Pesticides, petroleum products, and heavy-metal wastes are examples. The damage caused by this type of pollutant can be irreversible.

Both persistent and non-persistent wastes are a concern if they become concentrated enough to harm living organisms. How can we detect the presence and determine the concentration of harmful substances in our environment? A detailed knowledge of chemistry helps us accomplish this. Most pollutants eventually find their way into water, either by being washed out of the atmosphere in rainfall and snow such as acid precipitation, or by direct seepage. By knowing the correct chemical tests for a pollutant, it is possible to determine the presence, or absence, of that pollutant within a water sample. In the next two investigations, you will test water samples for phosphates and nitrates (Investigation 3-H) and for carbon dioxide (Investigation 3-I).

Cool Tools

Bee Probes

Honeybee colonies have been used for centuries to provide honey and pollinate flowers, fruit trees, and other crops. But now, scientists have found a new use for the busy insect. Honeybee colonies are used globally to indicate the presence of hazardous materials in the environment. Millions of established colonies provide constant monitoring. Because honeybees can live under many different environmental conditions, small colonies can be introduced almost anywhere hazardous substances are suspected.

Scientists at the University of Montana have designed electronic beehives (right) that provide useful information about the environment. Electronic hives record the behaviour of every bee, including how often it flies, the pollen it gathers, and how the bees control the environment in the hives. Pollutants brought into the hives by the bees are detected using electronic instruments attached to the hives.

1. Bees leave the hives and pick up water, nectar, pollen, and airborne water particles.
2. When bees return to the hives, they fan their wings to control the air temperature in the hives.
3. Pollutants in the environment that were picked up by the bees are released into the air of the hives as the bees fan their wings.
4. Pollutants released by the bees are measured using chemical probes attached to the hives.
5. The chemical data are analyzed to determine which pollutants were brought into the hives from the local environment.

Thinking Critically

1. Why are bees useful animals for detecting pollution?
2. What are common causes of pollution in your area?
3. Research how a miner's canary was used to warn about hazardous substances. How is this similar to how honeybee colonies are being used?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Would you like to know more about the use of bees as a tool for detecting environmental hazards? Go to the web site above, and click on Web Links to find out where to go next. In your notebook, write how you think other environmentally sensitive organisms could be used to protect the environment.

INQUIRY

INVESTIGATION 3-H

SKILLCHECK

Initiating and Planning

✸ Performing and Recording

✸ Analyzing and Interpreting

Communication and Teamwork

Measuring the Amount of Phosphates and Nitrates in a Water Supply

You may recall from Topic 1 that phosphorus promotes plant growth. The most likely source of phosphorus is in the form of phosphate, which occurs naturally in most soil and water in amounts under 0.5 ppm. Nitrogen is most often available in the form of nitrates, and clean water naturally contains from 0.1 to 0.3 ppm. Excessive amounts of nitrates in water is usually a sign of decomposition of organic matter. Tiny plants called algae may form a dense growth or "algal bloom." This is often the result of excess phosphates and nitrates that enter water sources from sewage and agricultural run-off. In time the algae dies, and decomposition of the algae leads to low oxygen levels. This may lead to death or injury to aquatic animals. The strong smell of decay is often an indication that this process is occurring.

CONTINUED ▶

Question

How can you determine the presence of phosphates and nitrates in a sample of water?

Prediction

Make a prediction about which of the water samples contain phosphates or nitrates.

Safety Precautions

- Dilute ammonium hydroxide solution is corrosive. Clean up any spills on the lab bench or floor immediately and inform your teacher. If you spill on your skin, wash the area immediately with lots of cool water.

Apparatus

test tubes
medicine droppers
test tube rack
water test kit (LaMotte™)
graduated cylinder

Materials

4 water samples (distilled water; water containing fertilizer; water containing dishwashing detergent; water from a local pond, lake, or stream)
dilute ammonium hydroxide solution
magnesium sulfate solution

Part 1

Testing for Phosphates

Procedure

1. Label four clean, dry test tubes to correspond with the four water samples.

2. Place about 10 mL of each water sample into its corresponding test tube.
3. Using the medicine dropper, carefully add 20 drops of the dilute ammonium hydroxide solution to each of the test tubes.
4. Carefully add 2 mL of magnesium sulfate solution to each test tube and let stand in the test tube rack undisturbed for 3–5 min.
5. The formation of a precipitate (magnesium phosphate) indicates the presence of phosphate within that water sample.

Skill FOCUS

For tips on measuring the volume of liquids, turn to Skill Focus 5.

Part 2

Testing for Nitrates

Procedure

Carefully study the instructions and procedures that come with your water test kit. The following steps are used with the LaMotte™ kit.

1. Pour distilled water into the test tube that is supplied with your kit until it reaches the 2.5 mL mark.
2. To the water sample add the mixed acid reagent to bring the volume to the 5 mL mark.
3. Cap the test tube and invert it three or four times. Let the test tube stand undisturbed for 2 min.
4. Using the measuring spoon supplied with the test kit, add one level spoonful of the nitrate-reducing reagent to the test tube.
5. Cap the test tube and invert it continuously for 1 min. Let the test tube stand undisturbed for 10 min.

⑥ Swirl the test tube gently before removing the cap and inserting the test tube into the nitrate-N comparator with the axial reader.

⑦ Compare the test tube containing the water sample with the colour standard that it matches. Read the number off the nitrate-N comparator and **record** the reading.

⑧ Convert the reading to parts per million (ppm) of nitrate by multiplying by 4.4 and **record** your answer.

⑨ Repeat steps 1–8, replacing the distilled water with each of the other three samples in turn.

⑩ When you have completed the investigation, remove your gloves and wash your hands with soap and water.

Analyze

1. Which of the water samples contained phosphates? Do the results of your testing match what you would expect to find for each sample?
2. Which of the water samples contained nitrates? Do the results of your testing match what you would expect to find for each sample?
3. What was the purpose in testing the distilled water? The water containing fertilizer?

Conclude and Apply

4. Do you consider the water sample from the local pond, lake, or stream to be polluted? Explain your reasoning.

Did You Know?

Water-quality technicians frequently use dyes to track the movement of wastes in sewage systems to locate cracks in pipes that are in need of repair. With large-volume systems, or those with many outlets, the dyes are often hard to spot, so caffeine was suggested as a substitute. Caffeine has no natural occurrence in the environment other than from human waste. It is almost completely unchanged as it passes through the body and is easy to detect. However, a study in Seattle, Washington, found that two-thirds of test sites in Puget Sound were already polluted with caffeine. Apparently, this pollution was caused by motorists and coffee-stand operators dumping cold coffee into sewer systems, which then mixed into the general environment. Unfortunately, this meant that the traditional dye method had to remain in use.

Did You Know?

Most laundry and dishwasher detergents contain water softeners (usually sodium carbonate), which help soaps remain effective even in hard water. Hard water contains calcium, magnesium, and/or iron salts. These salts react with the soapsuds to form curds and reduce the cleaning power of the soap. By adding sodium carbonate, the calcium, magnesium, or iron binds to the carbonate instead of the soap suds.

INQUIRY

INVESTIGATION 3-I

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- Communication and Teamwork

Testing Water Quality

One method of determining the quality of a water sample is to figure out the amount of oxygen and carbon dioxide gas dissolved in the water. Polluted water often has low oxygen content. It may also have a high carbon dioxide content, since a by-product of bacterial respiration is carbon dioxide. Clean water usually has high oxygen content. Other factors also affect the oxygen content of water. For instance, turbulent water has more water mixed into it than still water does, and temperature affects how much dissolved oxygen the water can hold. When analyzing a water sample for dissolved oxygen content, you should consider when and where the sample was taken.

Question

How do temperature and turbulence affect the oxygen content in water?

Hypothesis

Form a hypothesis about the effect of temperature and turbulence on the oxygen content in water.

Safety Precautions

- Dilute sodium hydroxide solution is corrosive. Clean up any spills on the lab bench or floor immediately and inform your teacher. If you spill any on your skin, wash the area immediately with lots of cool water.

Apparatus

3 Erlenmeyer flasks
1 medicine dropper
hot plate
beaker tongs or oven mitts
400 mL beaker
water test kit (Hach™)

Materials

Part 1	Part 2
water samples (100 mL of tap water, 100 mL of aquarium or pond water, 2 sealed flasks containing 100 mL of boiled and cooled tap water)	water samples (100 mL of tap water, 100 mL of water from an aquarium or pond)
	phenolphthalein solution
	0.4% sodium hydroxide solution

Part 1

Dissolved Oxygen

Procedure

Carefully study the instructions and procedures that come with your water test kit. The following steps are used with the Hach kit.

1. Add tap water to the Dissolved Oxygen bottle (round bottle with glass stopper) supplied with your kit by allowing the water to overflow the bottle. To avoid trapping air bubbles in the bottle, tilt the bottle slightly and insert the stopper quickly to force out air bubbles. If bubbles become trapped in the bottle in step 2, discard the sample before repeating the test.

2. Add the contents of Hach powder pillows #1 (manganous sulfate) and #2 (alkaline iodide azide) to the BOD bottle. Insert the stopper supplied for the bottle (making sure that there is no air trapped inside) and shake vigorously to completely mix the solution. A small amount of powder may remain at the bottom of the bottle. This will not affect the test results.

3. If oxygen is present in the sample, a brownish-orange precipitate will form.

4. Let the bottle stand undisturbed until the precipitate settles halfway to the bottom of the bottle. The top half of the sample should appear clear. Shake vigorously and again let the bottle stand undisturbed until the precipitate settles halfway to the bottom.

5. Add the contents of powder pillow #3 (sulfamic acid) to the sample and shake. The precipitate will dissolve and the water will turn yellow.

6. Carefully pour the yellow DO sample to completely fill the measuring tube that is supplied with your kit and add this to the square mixing bottle supplied with your kit. Measure and pour a second full measuring tube of the same sample into the mixing bottle.
7. Add one drop of sodium thiosulfate titrant to the square mixing bottle and swirl the bottle to mix the titrant into the sample.
8. While swirling, continue to add titrant *one drop at a time* to sample until the sample just barely becomes clear and stays clear after swirling. *Count the number of drops needed to change the sample from yellow to clear.* **Record** the number of drops of titrant needed to turn the sample clear.
9. Repeat steps 1–8 using the aquarium or pond water in place of the tap water.
10. Unseal one of the flasks of boiled, cooled water. Measure the amount of dissolved oxygen by repeating steps 1–9 with this water in place of the tap water.
11. Unseal the other flask of boiled, cooled water. Pour the contents of the flask into a beaker. Aerate the water by pouring the water back and forth between the beaker and the flask for 1 min. Return the water to the flask and measure the amount of dissolved oxygen in the sample by repeating steps 1–9 using this water in place of the tap water.

Part 2

Dissolved Carbon Dioxide

Procedure

1. Place the 100 mL sample of tap water into an Erlenmeyer flask.
2. With a dropper, add *five drops of phenolphthalein solution* to the sample. Mix by gently swirling the flask. *If* a light pink colour *forms and stays*, *no* carbon dioxide is present. **Record** this result. *If* a light pink colour *forms and then quickly disappears*, carbon dioxide gas is present. Continue with the procedure.
3. With a clean dropper, add *sodium hydroxide solution one drop at a time* to the sample, until the sample just barely becomes light pink and remains pink after swirling. *Count the number of drops needed to change the sample pink.* **Record** the number of drops of sodium hydroxide needed to turn the water sample pink.
4. Repeat steps 2 and 3 with 100 mL of aquarium or pond water.
5. When you have completed the investigation, remove your gloves and wash your hands with soap and water.

Analyze

1. Find the amount of dissolved oxygen in each sample of water used in Part 1 in parts per million (ppm). Each drop of titrant equals 0.5 mg/L (0.5 ppm) of dissolved oxygen, so divide the number of drops of titrant needed to produce a clear solution by 2. Carry your divisions to one decimal place.
2. Find the amount of dissolved carbon dioxide in each sample of water used in Part 2 in parts per million (ppm). To do this, multiply the number of drops of sodium hydroxide needed to produce a pink solution by 5.

Conclude and Apply

3. How does the temperature of water affect its ability to contain dissolved oxygen?
4. How does turbulence affect water's ability to contain dissolved oxygen?
5. Based on your measurements of dissolved oxygen and carbon dioxide, would you consider the aquarium or pond water to be polluted? Explain your reasoning.

Biological Indicators of Water Quality

Most types of pollution lower the ability of an environment to support life. For aquatic systems, pollution often decreases the amount of dissolved oxygen in the water. In effect, pollutants decrease the number and variety of organisms that are present in the affected area. This decrease in biological diversity has been well documented for aquatic systems and is a useful indicator of the quality of any source of water.

Although there are no defined standards for diversity, there are a few organisms that are typical to both "clean" and "polluted" waters. These organisms are generally referred to as **biological indicators**. For example, some species of fish, such as trout and perch, are found only in clean, well-oxygenated bodies of water. In contrast, carp and catfish are two fish species that can tolerate higher levels of pollution.

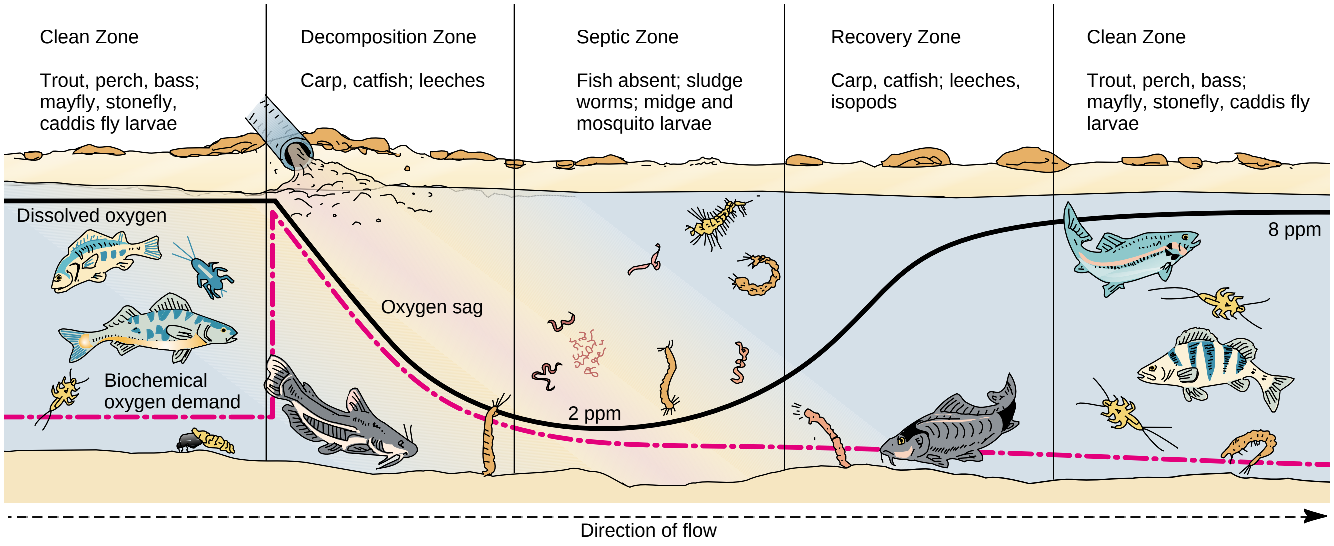

Clean Zone
Trout, perch, bass; mayfly, stonefly, caddis fly larvae
Decomposition Zone
Carp, catfish; leeches
Septic Zone
Fish absent; sludge worms; midge and mosquito larvae
Recovery Zone
Carp, catfish; leeches, isopods
Clean Zone
Trout, perch, bass; mayfly, stonefly, caddis fly larvae
Dissolved oxygen
Oxygen sag
8 ppm
Biochemical oxygen demand
2 ppm
Direction of flow

Figure 3.22 Oxygen sag downstream of an organic source. A great deal of time and distance may be required for the stream and its inhabitants to recover.

The most useful organisms for a biological indicator of water quality are the **macroinvertebrates** — organisms visible to the unaided eye and lacking a backbone. The macroinvertebrates in the lakes, rivers, and creeks around you are crustaceans (e.g., crayfish), molluscs (e.g., clams and mussels), gastropods (e.g., snails), oligochaetes (e.g., worms), and insects. Since the larval forms of insects are the most numerous of the macroinvertebrates that are usually found, they are generally the focus of most stream surveys. A survey of the number and type of macroinvertebrates found in a body of water can provide a general indication of whether pollutants are present or not. Table 3.5 shows some examples. However, it is important to remember that organisms that are representative of poor water quality may be found in any type of water, whereas organisms representative of good water quality are found only in water of good quality!

Table 3.5

Water Quality Indicators

Good Quality (8–10 ppm of oxygen)	Moderate Quality (4–8 ppm of oxygen)	Poor Quality (0–4 ppm of oxygen)
stonefly nymph	dragonfly nymph	midge larvae
mayfly nymph	damselfly nymph	blackfly larvae
caddisfly larvae	cranefly larvae	pouch snail
water penny beetle	clams and mussels	leech
riffle beetle	sowbug	aquatic worm
gilled snail	crayfish	planorbid snail

Figure 3.23 Scientific research in protected areas, such as Riding Mountain National Park, helps us monitor the health of our ecosystems.

Pause& Reflect

Lichens are rootless organisms that are a combination of a fungus and a green alga or photo-synthetic bacteria. One of the hardiest organisms found on Earth, they are relatively unaffected by extremes in temperature. They can survive long periods of drought, and grow almost anywhere, because they absorb all of their nutrients directly from the atmosphere. But lichens cannot tolerate poor air quality!

Because different varieties of lichens are more sensitive to certain pollutants than others, an early warning system for air pollution has been devised using them. The presence or absence of specific lichen varieties alerts scientists to the presence of pollutants in an area long before other organisms are affected.

Find out which other plants can be used as acid-base indicators and list them in your Science Log.

DECISION-MAKING

INVESTIGATION 3-J

SKILLCHECK

Initiating and Planning

✹ Performing and Recording

✹ Analyzing and Interpreting

✹ Communication and Teamwork

Assessing Water Quality with Macroinvertebrates

Think About It

According to WHO's Global Water Supply and Sanitation Assessment for the year 2000, nearly 1.1 billion people lack access to improved sources of water. What affects the quality of water sources in your area and what issues are involved? In this investigation you will use a technique that provides a scientific basis for assessing water quality.

How Can Science Help?

By 2015, the United Nations Millennium Declaration pledges "to reduce by one-half the proportion of people without sustainable access to adequate quantities of affordable and safe water." Efforts by WHO, UNICEF, and other international organizations have contributed to global awareness of the problem and the establishment of international programs. Between the years 1990 and 2000, these programs increased access to improved sources of water from 79 to 82 percent of the world's population. Since the early 1990s, organizations worldwide have been participating in monitoring programs for water supplies. These monitoring programs provide the reliable and consistent statistics needed for informed policy making.

Safety Precautions

- Conduct this investigation only under the supervision of your teacher.
- Be careful when handling living organisms.
- Be sure to wash your hands when you are finished the investigation.

Apparatus

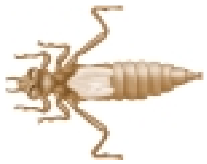
1.2 m^3 nylon screen or mesh net with a metal rim
turkey baster or plastic forceps
pan or paper plate
hand lens
thermometer
pH paper or universal indicator
portable water test kit (optional)
illustrated classification keys to the macroinvertibrates
(*A Guide to the study of Fresh-Water Biology* by Needham and Needham is a good reference)

Procedure

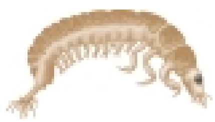
1. Collect a sample of organisms from the river or stream bottom by placing the nylon screen or mesh net against the bottom and kicking against the bottom upstream of the net for at least 1 min. You should overturn and scrape any rocks that are present. Be sure that your net is placed to intercept all of the floating debris stirred up by the kicking.

Note: If you are testing a pond or lake where there is no current, use the net with a metal rim to scoop material from the bottom mud, especially around the base of any weedy areas.

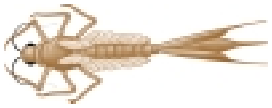
2. You should examine the larger bits of wood that are disturbed by your kicking, since some of the organisms you are attempting to collect may be stuck to the underside of the wood.
3. Wash away the mud and dirt by shaking the screen or net while holding it partly under the surface of the water.
4. Using the turkey baster or plastic forceps, transfer any organisms collected to the pan or paper plate and group them by shape.
5. Using a classification key and a hand lens to examine each organism, identify as many of the organisms as you can. The following illustrations may help in your identifications.



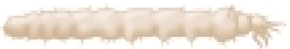
(a) Dragonfly Nymph



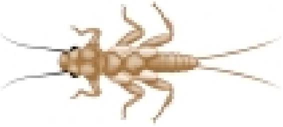
(b) Caddisfly Larva



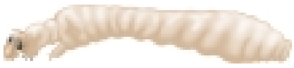
(c) Mayfly Nymph



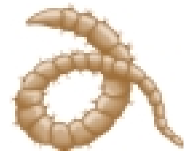
(d) Crane Fly Larva



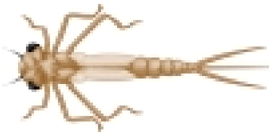
(e) Stonefly Nymph



(f) Black Fly Larva

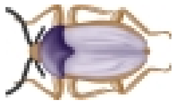


(g) Aquatic Earthworm or Bristleworm



(h) Damselfly Nymph

(i) True Midge Larva



(j) Water Penny Beetle

6. As you identify an organism, **record** this fact in a data table such as the one shown. Check the box next to the name of the organism.

7. Return the organisms to the water as close as possible to the site from which they were obtained.

8. As a group, collect some or all of the following information.
   - a photograph or sketch of the collection site
   - the appearance of the water
   - the pH of the water
   - the temperature of the water
   - evidence of human activity near the water (structures, artifacts)
   - water quality measurements using a water test kit (dissolved oxygen, nitrates, phosphates)

9. Wash your hands before eating or drinking.

* Sensitive	Moderately sensitive	Tolerant
☐ stonefly nymph	☐ dragonfly nymph	☐ midge larvae
☐ mayfly nymph	☐ damselfly nymph	☐ blackfly larvae
☐ caddisfly larvae	☐ cranefly larvae	☐ pouch snail
☐ water penny beetle	☐ clams and mussels	☐ leech
☐ riffle beetle	☐ sowbug	☐ aquatic worm
☐ gilled snail	☐ crayfish	☐ planorbid snail
	Index value **(B)** Boxes checked × 2 = __	**Index value** **(C)** Boxes checked × 1 = __

Total Index Value = ____ + ____ + ____ = ____
(A) (B) (C)

Water Quality Rating (by total index value)

Excellent (>22) Good (17–22) Fair (11–16) Poor (<11)

*Sensitive organisms require water of good or excellent quality.

Analyze

1. Using the measurements and results obtained in your survey, assess the quality of water at your sample site.
2. Identify any sources of material entering the body of water where you are sampling, and suggest how the material might affect the water quality.
3. If the source(s) in #2 are from human activity, identify an alternative course of action for each source, to diminish any negative effect on water quality.
4. You were asked to return the organisms to their original location. Why?

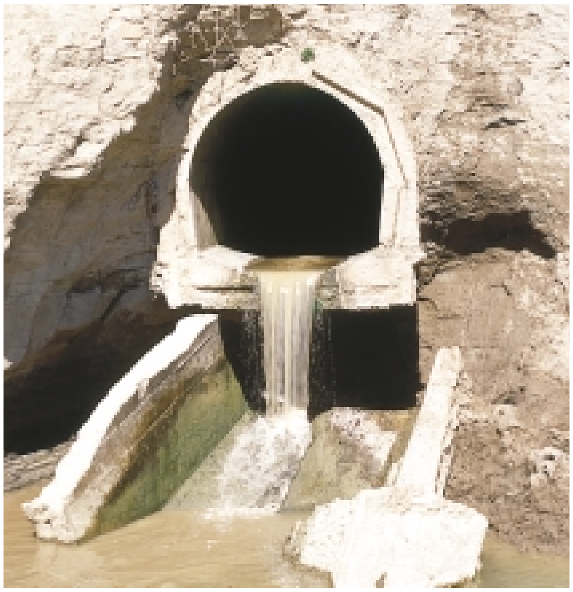


Figure 3.24 Sewer outfalls, industrial effluent pipes, acid draining out of abandoned mines, and other point sources of pollution are generally easy to recognize.

Point Versus Non-point Sources

Determining the presence of pollutants within a body of water is really only a first step. Ideally, we must be able to monitor the changes in the concentration of those pollutants and track them to their source. This is where it gets tricky! As shown in Figure 3.24, pollutants that enter the environment from specific locations — **point sources** such as drainpipes and smokestacks — are easy to monitor and control, but what about those pollutants that have had a chance to mix into the environment before they are detected? As shown in Figure 3.25, the emission of pollutants from **non-point sources** — such as feedlots, golf courses, construction sites, and fertilized fields — are often separated both in time and location from the source, since the pollutants become highly dispersed as they travel. This type of pollutant is much harder to control because the emissions do not occur regularly. Acid rain is a good example of just such a non-point source pollutant.

Environmental organizations, both governmental and private, agree that the cheapest and most effective way to reduce pollution is to reduce the emission of pollutants. Efforts since the early 1970s have led to new regulations and emphasis on the 4 Rs of the environmental movement — Reduce, Reuse, Recycle, and Recover — but as you will see in the next Topic, even this comes with its own set of problems!

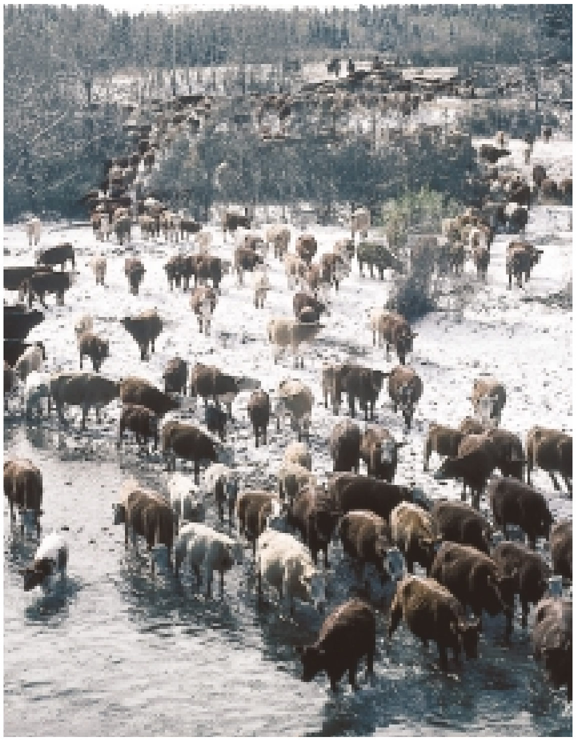


Figure 3.25 Water pollution occurs with bank erosion and bacterial deposition. The effects of non-point sources like this one are difficult to determine since the pollutants are scattered or diffused.

TOPIC 5 Review

1. A student claims that it is unfair to judge the quality of a water sample based on just one result. Would you agree or disagree? Explain your answer.

2. What would be the effect of an increase in water temperature on the organisms that live within that water? Explain.

3. Explain how phosphates and nitrates create low-oxygen conditions within a body of water.

4. **Apply** A science class has completed a water-sampling project of the river that flows through town. At each of the marked sites, macroinvertebrates were identified and counted. The class noted that the population of bottom-dwelling insects showed marked changes relative to the location on the river from which the sample was taken.

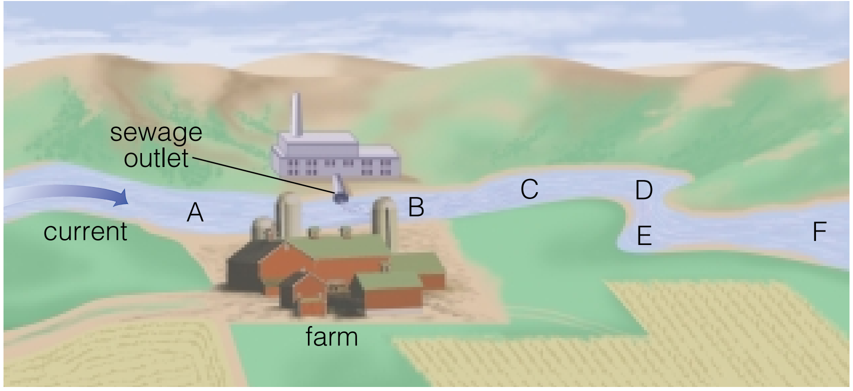
Site number	Number of each organism detected				
	Aquatic worms	Midgefly larvae	Leeches	Dragonfly nymphs	Stonefly nymphs
A	23	17	32	155	264
B	257	125	0	0	0
C	224	117	29	0	0
D	210	98	40	37	0
E	67	78	43	81	13
F	36	24	35	94	97

(a) Based on the numbers and types of organisms detected at each site, would you consider site C to be of low-, medium-, or high-quality water? Why?

(b) Site E is found to have a high number of aquatic worms living there. Aquatic worms are known to be tolerant of low-oxygen conditions. Would you consider site E to be polluted? Explain your answer.

(c) The main difference between sites C and D is a small set of rapids between the two sites. Explain how these rapids influence the presence of dragonfly nymphs found at site D.

(d) The class decides that both the farm and the town's sewage outlet contribute to the lower quality of the water downstream of the town. What is the major difference between the two sources?



TOPIC 6

N.I.M.B.Y. — There Is No Away in Throwing

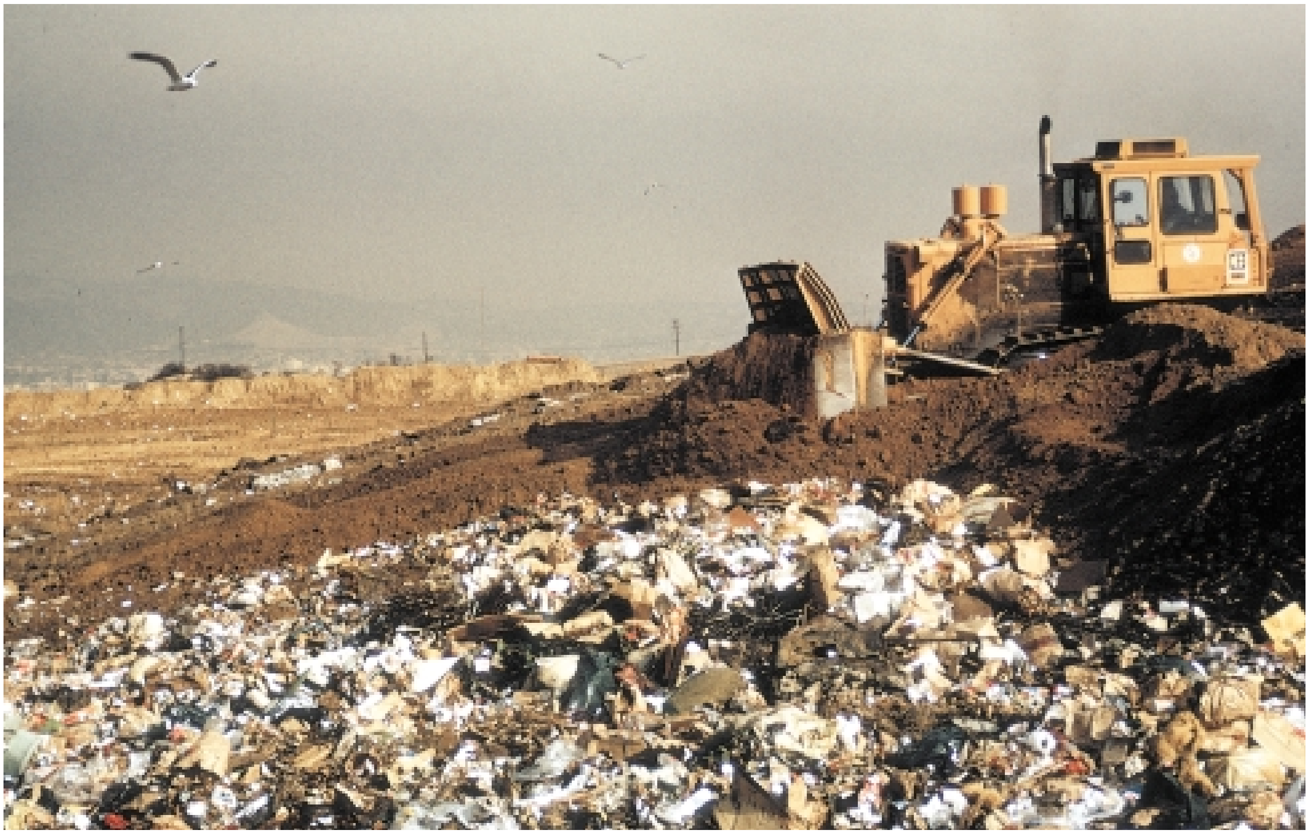


Figure 3.26 Bulldozers pack down trash at a municipal landfill site.

In the past, pollution was primarily a local problem. With the advent of industrialization, the invention of motorized vehicles, and the population explosion, there was a huge increase in the production of goods and services. This was accompanied by a tremendous growth in waste by-products.

The acronym N.I.M.B.Y. (Not in My Backyard) is familiar to most people these days. It is an expression that summarizes people's growing awareness of the problems associated with waste production and storage. Human beings produce over 1000 billion kg of solid waste every year and it must be removed and stored. We may not even realize that wastes are entering our "backyard." Solid wastes are the easiest of the wastes to notice and the least mobile, but what about the wastes in our air and water?

Blowing in the Wind

In previous Topics, you have seen how acid precipitation results from pollutants entering the atmosphere, travelling great distances, and then creating environmental problems when they fall to the ground. In the past, natural sources such as forest fires and volcanic eruptions introduced the majority of pollutants into the atmosphere. While this is still true for most of the southern hemisphere, human activities are now the biggest source of airborne pollutants in the northern hemisphere. Besides the carbon, nitrogen, and sulfur oxides that you have learned about, soot from combustion of fossil fuels and dust from wind erosion accelerated by agriculture are the most common pollutant particles. In weaker concentrations are heavy metals such as lead, nickel, and copper, which result from industry or combustion processes. At one point in the early 1970s, the concentration of airborne lead in the northern hemisphere was about a thousand times higher than normal. Due to the wind patterns in the northern hemisphere, airborne particles and gas pollutants tend to concentrate at higher latitudes and are eventually washed out of the atmosphere by rain and snow.

DidYouKnow?

Inuit people living on Broughton Island in the high Arctic have higher concentrations of polychlorinated biphenyls (PCBs) in their blood than any other known population. These highly toxic organic chemicals result from industrial fires and are known to bioaccumulate in the food chain.

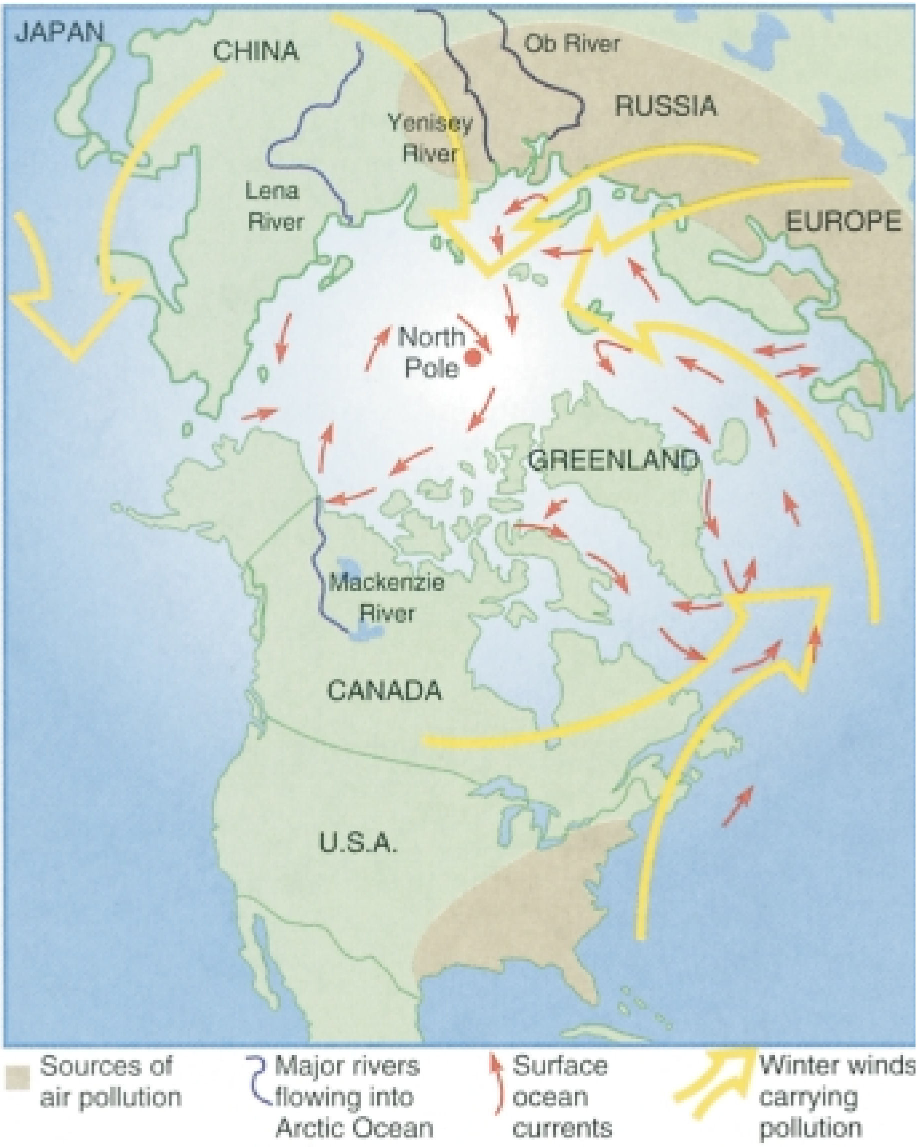


Figure 3.27 Air pollution from heavily industrialized regions in Europe and America are transported by circumpolar winds to the Arctic, where high levels of smog accumulate. The average transit time from Russia to Canada is only about three days.

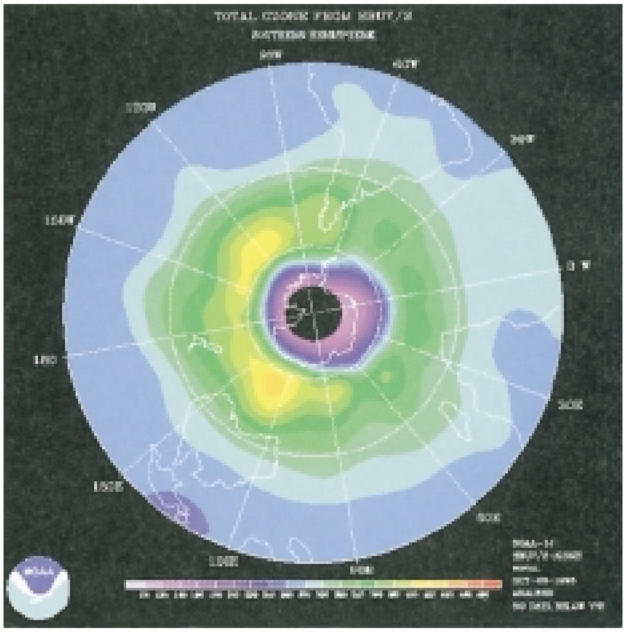


Figure 3.28 Ozone depletion over the South Pole is shown in this satellite image from October 5, 1995. Outside the polar vortex, green and yellow areas show raised ozone levels. Over Antarctica (outlined in white), however, stratospheric ozone levels are reduced by 80 percent or more from normal levels. The dark spot over the South Pole is a function of the measuring system.

Stratospheric Ozone and CFCs

Chlorofluorocarbons (CFCs) are yet another human-made pollutant that has far-reaching effects. Until recently, CFCs were used as:

- an agent in forming Styrofoam™
- propellants in aerosol cans
- coolants in air conditioners and refrigerators

Cheap, non-toxic, and stable, CFCs seemed ideal for these purposes. The discovery of a hole in the protective ozone layer over the Antarctic in 1985 (the result of the ultraviolet breakdown of the CFCs) was a real shock.

Ozone at Earth's surface is an irritating toxin, but ozone high in the stratosphere prevents ultraviolet radiation from reaching the surface of Earth. Without this protection, biological organisms at the surface experience damage to cells. In the stratosphere, ultraviolet light reacts with the CFC molecules to produce chloride ions. These chloride ions act as a catalyst for the breakdown of ozone ($O_{3(g)}$) gas to normal oxygen gas ($O_{2(g)}$). In 1997 the ozone hole over the Antarctic was larger in area than the continental United States, ozone levels over the Arctic were 40 percent lower than normal, and about 10 percent of all stratospheric ozone worldwide was destroyed! Since then, an 81-country agreement to stop the production and use of CFCs has helped. Unfortunately, the most useful property of CFCs for us — their stability — is also the biggest problem. Even though CFCs are no longer widely used, they will persist in the atmosphere for many years.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

What is the state of the ozone layer at this moment? Go to the web site above, and click on Web Links to find out where to go next. How does it compare to the information in Figure 3.28? Write your answer in your notebook.

Across Canada

Since the largest ozone depletion happens around the Poles, what better place for Hans Fast and other scientists to study this phenomenon than in the Canadian North? The location of the Arctic Stratospheric Ozone Observatory at Eureka, Nunavut, was no accident. Scientists needed to find a place with low enough latitude that the Sun was visible in early spring when ozone destruction is at its highest. There had to be enough Sun for scientists to use certain instruments for measuring ozone and the gases that affect ozone. The observatory also needed to be far from sources of pollution but close enough to a base station where scientists could live. Eureka has it all — its latitude is 80°N and it has a weather station that scientists can use for support.

About ten scientists study ozone at the observatory every winter and spring, but not at the same time. Hans visits the observatory every fall and spring to make sure everything is running smoothly. He also measures atmospheric gases that control the concentration of atmospheric ozone. Scientists at the observatory battle temperatures of –40° to –50°C in February and March. With such low temperatures, Hans and other scientists observe the atmosphere through hatches in the roof. Electric heater wires and heaters keep instruments mounted on the roof from freezing. These instruments measure the concentration of ozone and variations of tiny particles that are related to ozone destruction. Spectrometers also measure the concentration of atmospheric gases that have chemical reactions with ozone.

The results of all these tests show that the ozone layer in the Arctic is getting thinner. But since harmful substances have been reduced over the past ten years, Hans and other scientists think this will improve. Hans says that it'll be another few decades of measurements and observation before they can verify their predictions.

Controlling Water Pollution in Surface Waters

As you have learned, pollutants entering the general environment eventually find their way into our lakes and rivers as they are washed from the soil or out of the atmosphere. Most countries in the world have now enacted legislation to control the dumping of waste products into surface waters. Targeting point sources especially, these controls have greatly reduced the amounts of pollutants entering surface waters.

Most surface water pollution is due to everyday activities such as washing clothes or watering lawns. The resulting waste water is channeled away either through storm sewers for surface runoff or sanitary sewers for sewage. The law requires that the nitrates and phosphates from household detergents and other cleaning agents be removed before the water is returned to a watercourse. Sewage must also be treated to reduce the amount of organic material contained and to destroy disease-causing bacteria and viruses. As illustrated in Figure 3.29, chlorinating the waste water has been the method of choice for destroying bacteria and viruses, but recently high-intensity ultraviolet light has been used as well. What can be done about the problem of run-off from streets and yards, which carries fertilizers, pesticides, oils, and other chemicals into our surface watercourses? In addition, chlorinating waste water may result in the formation of cancer-causing agents. Is this an acceptable risk?

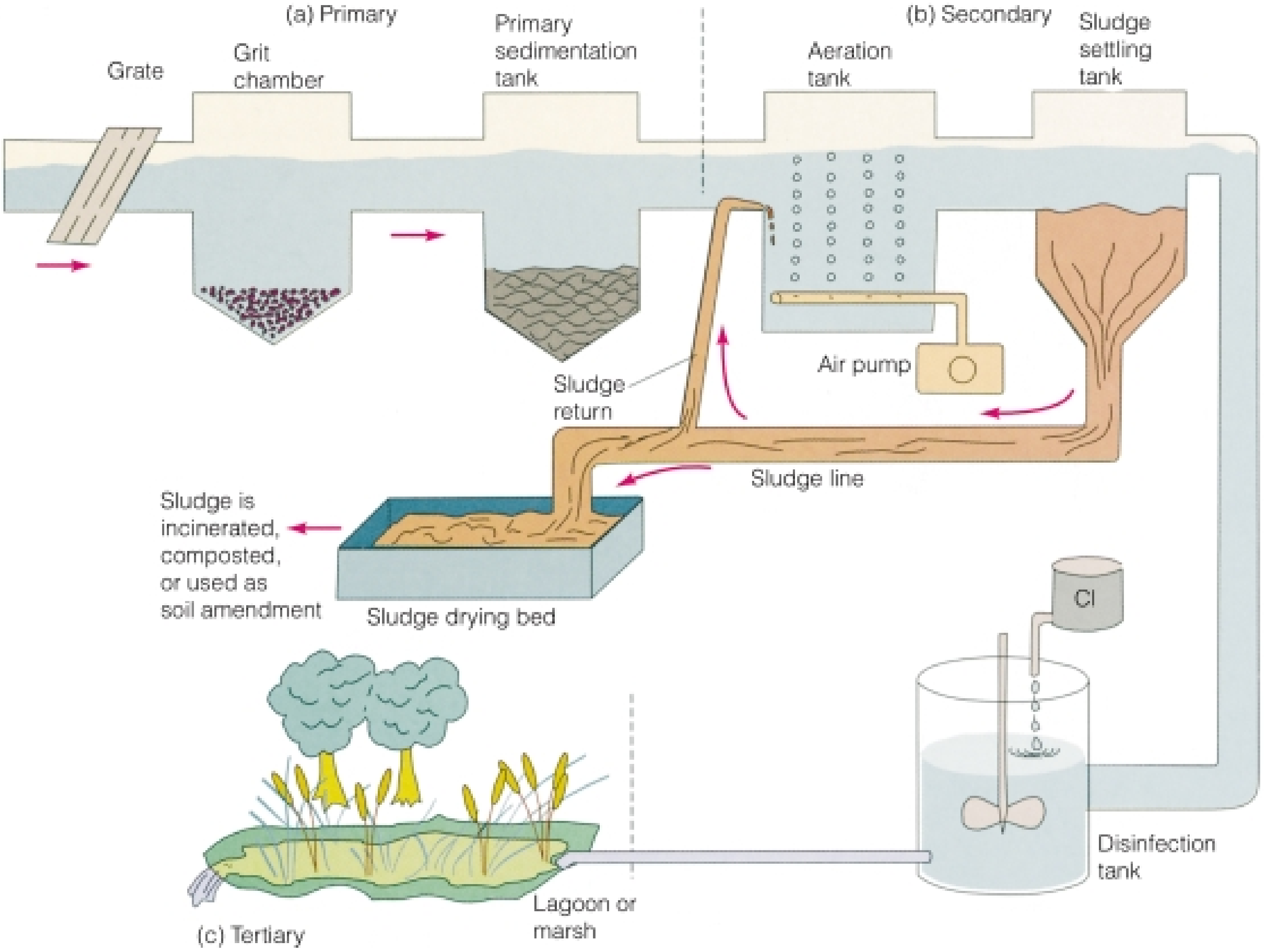


Figure 3.29 (a) *Primary treatment* physically separates large solids and suspended sediments. (b) *Secondary treatment* removes much of the organic compounds by bacterial decomposition. The resulting sludge is removed, and the remaining liquid effluent is treated by chlorinating or exposure to ultraviolet light to kill any disease organisms that have survived. (c) During *tertiary treatment*, percolation through soil into ground water, passage through a trickling bed evaporator and/or a lagoon or marsh removes the nitrates and phosphates that remain. A careful choice of the plants growing in the marsh can even remove some of the heavy metals within the effluent.

DidYouKnow?

According to Environment Canada, approximately 57 percent of Canadians are served by waste water-treatment plants, compared with 74 percent of Americans, 86.5 percent of Germans, and 99 percent of Swedes.

Figure 3.30 The water hyacinth plant removes many pollutants from water. Water hyacinths can be used at waste water-treatment facilities to clean water before it flows back into streams and aquifers.

Controlling Water Pollution in Ground Water

Most people think only of surface waters — oceans, lakes, rivers, and glaciers when they think of the effects of water pollutants. This is not where the attention of almost 8 million Canadians should be! About 26 percent of Canadians rely on ground water for their domestic water supplies. **Ground water** is water that filters down through soil and fills the spaces between particles of rock and soil, and the cracks and fractures in underlying rock. Like all water, ground water tends to flow down towards rivers, lakes, or the sea, but the rate at which ground water moves depends on how permeable the rock and soil formations are. Typically, ground water moves at an average of 15 m per year, although it is not unusual to find locations where a flow rate of a few centimetres per century is normal. There are some areas of this permeable material that can produce useful amounts of water when a well is drilled into them. These are referred to as **aquifers**. One common feature of aquifers is that the water is naturally filtered as it moves through and is usually free from bacterial contamination. Unfortunately, other contaminants dissolve into water and can become concentrated in aquifers. Problems with contamination are multiplying because of the increased use of toxic herbicides, pesticides, and solvents in industry and agriculture. Ground water contamination is very difficult, if not impossible, to clean up, so the best option is to avoid producing contaminants in the first place.

DidYouKnow?

The ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT states that:

"109(1) No person shall knowingly release or permit the release into the environment of a substance in an amount, concentration or level or at a rate of release that causes or may cause a significant adverse effect."

"112 Where a substance that may cause, is causing or has caused an adverse effect is released into the environment, the person responsible for the substance shall, as soon as that person becomes aware or ought to have become aware of the release, (a) take all reasonable measures to (i) repair, remedy and confine the effects of the substance, and (ii) remove or otherwise dispose of the substance in such a manner as to effect maximum protection to human life, health and the environment, and (b) restore the environment to a condition satisfactory to the Director."

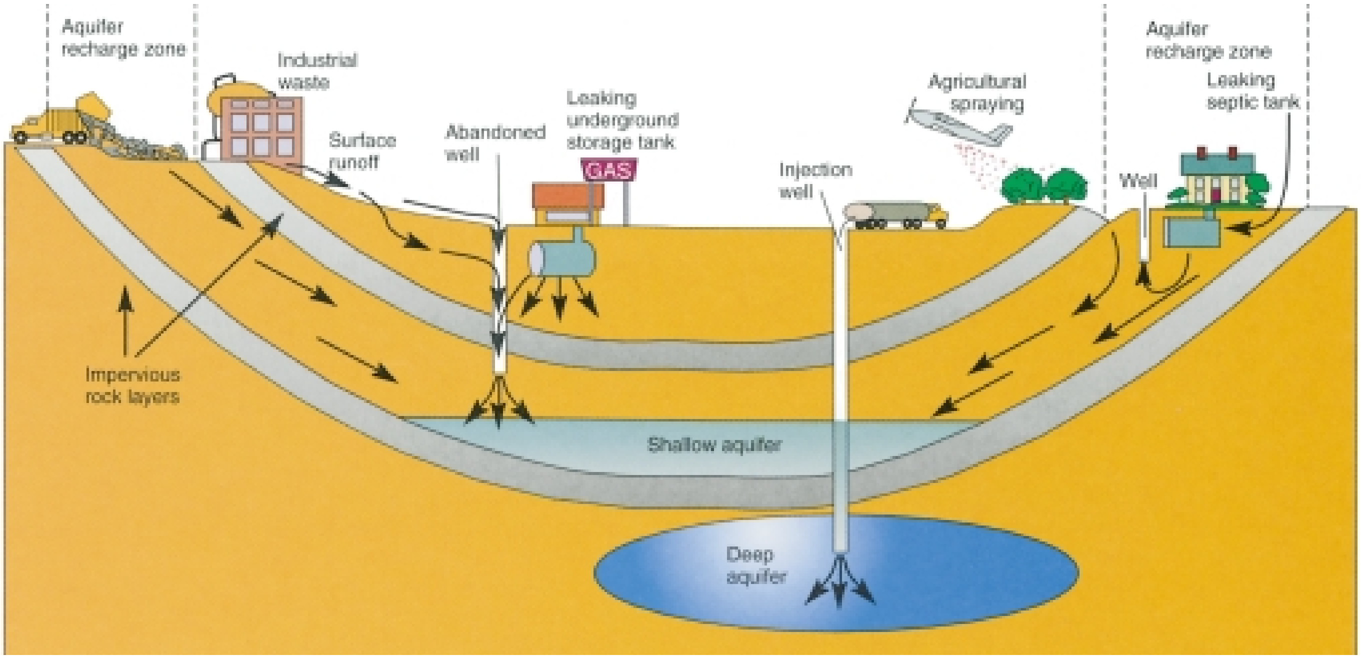


Figure 3.31 Possible sources of ground water pollution. Although much of what is shown in this illustration is now specifically prohibited in municipalities throughout Alberta, the result of these types of activities in the past require clean-up of some areas. What problems can you identify relative to the activities shown? Can you think of any practical ways to avoid the problems?

Pause& Reflect

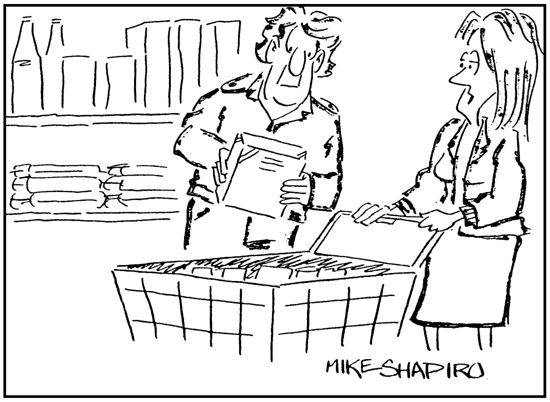
Demand for, and production of, automobiles soared in the 1950s and 1960s, resulting in great numbers of service stations to provide the fuel and oil to keep Canadians' vehicles on the road. Large underground storage tanks for petroleum products were installed at every site, but most of these tanks were made of steel and lacked any sort of corrosion protection. Within 15 years of installation, more than half the tanks were leaking significant amounts of petroleum contaminants into the soil. Consider that only one drop of oil can contaminate up to 25 L of water. How do companies clean up these sites? Do some research and write the answer in your Science Log.

Biodegradability and the Environment

Have you noticed that lately it seems as though everything is advertised as a "green" product? This designation was originally used to indicate that a product was biodegradable. **Biodegradable** substances are those organic compounds (natural or synthetic) that can be broken down by bacteria, fungi, and other simple organisms into carbon dioxide and water. With increasing public awareness of environmental hazards, it is more common now to find consumer products labelled "biodegradable" or "environmentally friendly." But can you take these claims at face value? While the label may proudly claim active ingredients are biodegradable, it doesn't tell you the other ingredients are not! A second problem is that while a compound may be biodegradable, it is not biodegradable under all conditions or in any reasonable period of time. Cultural anthropologists who have inspected old garbage dumps have recovered newspapers over 20 years old that are still readable! Landfills are often managed in a way that retards decay, because the production of gases resulting from decay is sometimes seen as a problem by the public. To avoid odours, the landfill may be kept dry. A lack of the proper mix of water, oxygen, and soil microbes prevent decomposition from occurring.

Bacteria and other microbes can decompose oil, but that same oil, when formed into a synthetic rubber tire, may never decompose. The organisms that would normally be responsible for decomposition cannot produce the chemical reactions or high temperatures necessary to break down the synthetic rubber. Even though oil and plastic contain almost exactly the same atoms, their different molecular structures result in different rates of decomposition. Table 3.6 illustrates the rate of biodegradation for some of the common substances found in household waste.

Finally, don't let labels fool you. A product may indeed be biodegradable and therefore a "green" product, but is it environmentally friendly? The decay products of many substances can actually be classified as hazardous wastes.



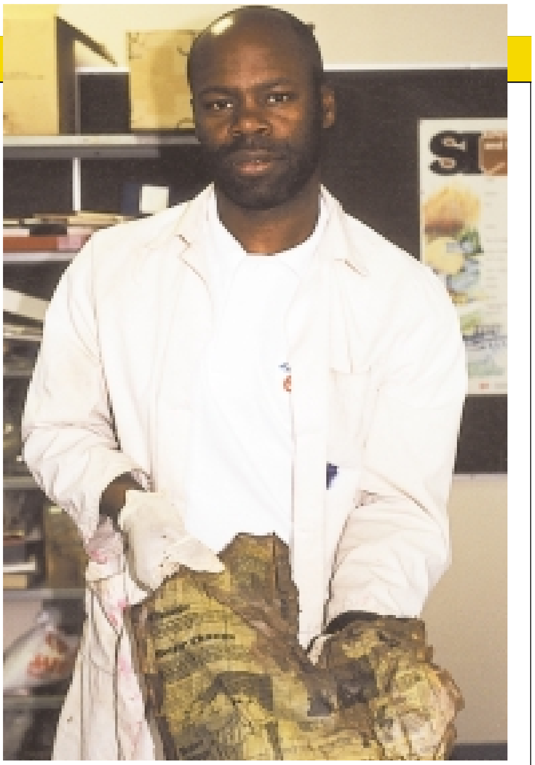
"It doesn't matter what it is. It's biodegradable."

Table 3.6

Rate of Biodegradation of Household Waste

Material	Time to biodegrade
cotton fabric	1–5 months
paper	2–5 months
orange peels	6 months
wool fabric	1–5 years
cigarette butts	1–12 years
milk cartons	5 years
plastic shopping bags	10–20 years
leather	25–40 years
nylon fabric	30–40 years
tin cans	50–100 years
aluminum cans	80–100 years
plastic 6-pack holder rings	450+ years

Career **CONNECT**



Dr. Roger Saint-Fort

Not many people think wading through garbage is an exciting way to make a living, but Dr. Roger Saint-Fort thinks so. As an environmental chemist and a Mount Royal College professor, he researches many aspects of the environment, from biological treatment of waste water and biofiltration to organic and inorganic contaminants in soil and ground water systems. In his classes he teaches students about:

- waste management (how to best manage garbage with the least harm to the environment)
- ground water contamination (chemicals in ground water systems)
- environmental instrumentation (the tools of the trade, including atomic absorption spectrometer, gas chromatographs, and infrared); these machines help chemists separate and analyze samples
- soil remediation (how to remedy contaminated soils)

Roger conducts research projects for various industries in the college laboratory. One of Roger's research projects involves analyzing garbage at Calgary landfills. He and his students filled huge drums with landfill material and let it settle for five years. Then they looked at what had biodecomposed as well as the leachate, the liquid produced by decomposing garbage. After five years, items such as pop cans, pizza boxes, and newspapers were virtually unchanged.

Roger says that some of the biggest challenges in this field are the misconceptions. People think that plastics are worse for the environment than are kitchen wastes. But kitchen waste decomposes and creates harmful gases and leachate — a more serious problem than plastics, which do not decompose. With the growing population causing more strain on waste management, Roger predicts the landfill will be full in about 30 years. To prevent this, he feels there needs to be a large-scale composting effort in cities and a sustainable effort to minimize waste rather than just reactions to the issue when it's too late.

There are many different research areas of environmental chemistry. Find out more about an area that interests you by doing research at the library or on the Internet. These areas could include: soil or ground water remediation; soil contamination, and screening for toxins in contaminated soil.

Word **CONNECT**

The word "degrade" comes from the Latin word *gradus*, meaning "step." The prefix *de-* is used to indicate removal or separation. "Degrade" is used in a chemical sense to signify the reduction of a chemical to a simpler molecular structure. The word itself is the Middle English version of the Old French verb *dégrader*, which in turn was taken from the ecclesiastical Latin verb *degradare*, used by clerics and monks to signify lower quality or character. Look up the meaning of "degrade" in a dictionary. In your notebook, explain how this meaning relates to the origins of the word.

*"They didn't tell **me** what to do with it. I thought they told **you** what to do with it."*

Hazardous Wastes

A **hazardous** waste is any discarded material that contains substances that are known to be poisonous, toxic, corrosive, flammable, or explosive. This certainly sounds serious, and it is! You would be surprised at the number of potential hazardous wastes to be found in your own home. The average Canadian household contains about 12–40 L of hazardous waste. You can easily recognize hazardous products because they are required to indicate their hazardous nature with a clear, highly visible signal word. The words DANGER and POISON are meant to indicate that the substance marked is highly toxic, corrosive, flammable, or explosive. WARNING and CAUTION are used to indicate a moderate or slight toxicity respectively. In addition, the substance must have all appropriate WHMIS symbols clearly displayed. Table 3.7 is not an exhaustive list of household hazardous substances, but you will probably recognize many of these in your own home.

Skill FOCUS

To review the WHMIS symbols, turn to Skill Focus 1.

Table 3.7

Hazardous Household Substances

Kitchen area	Bathroom area	Garage/storeroom
sink cleaners	tub and tile cleaners	paints, thinners, and glues
drain cleaners	disinfectant sprays	lawn and garden herbicides
floor wax/cleaner	nail polish and removers	ant traps or powders
oven cleaners	prescription medicines	degreasers
silver polish	hair dyes and cosmetics	antifreeze and gasoline
furniture polish	toilet cleaner	motor oil and brake fluid

You may notice that many of the hazardous substances in your home are used for cleaning purposes. The property these substances share is that they are all solvents. A **solvent** is any substance that can be used to dissolve another substance. Water, you may remember, is the most common solvent. Household products such as paint thinners, spot removers, turpentine, and nail polish remover are almost 100 percent solvent. Furniture oils, glues, paints, and shoe polish contain fewer solvents, but they do contain solvents. Many of these solvents are classified as organic because they are based on hydrocarbon compounds. It is important to note that ALL organic solvents are hazardous. Almost all organic solvents are poisonous if swallowed or inhaled in a large enough amount, and will cause rashes after repeated exposure. High concentrations of most solvents will result in dizziness, nausea, fatigue, and loss of co-ordination. Long-term exposure to many solvents can result in brain damage.

INQUIRY

INVESTIGATION 3-K

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

A Survey of Household Hazardous Wastes

Household hazardous wastes can be toxic to humans, and can burn, catch fire, or explode. The solvents in them evaporate quickly and are especially dangerous because often they are difficult to detect, having no colour or long-lasting smell. You might breathe in their vapours without realizing it. To reduce risk, always label them well (preferably in their original containers) and store in a secure, dry location. Seal all lids and caps and ensure that they are childproof. Keep these products away from heat and open flames. Some common toxic organic solvents in hazardous household products are:

- aromatic hydrocarbons (toluene, xylene)
- isopropyl alcohol or methyl alcohol
- chlorinated hydrocarbons (ethylene dichloride, methylene chloride, perchloroethylene, trichloroethylene, trichloroethane)
- naphthas
- petroleum solvents (kerosene, gasoline, mineral spirits)
- turpentine and acetone

Skill FOCUS

For tips on using the Internet and making graphs, turn to Skill Focus 9 and 10.

Finally, although latex paints are water-based, they are not without toxic risk. Some latex paints contain a mercury-based fungicide as a preservative. As a heavy metal, mercury is toxic.

Part 1

Question

How many and which types of hazardous wastes are found in the average household?

Safety Precautions

- Take care when inspecting products that you identify in your search. Remember these are HAZARDOUS products. Do not spill the contents during your inspection and avoid any container that is leaking. Wash your hands thoroughly if any of the products touches your skin, and after you finish your survey.

Apparatus

felt pens or coloured pencils

Materials

poster paper

Procedure

① Search your home for products likely to be hazardous. You may wish to enlist the help of a responsible adult. In general you will look for, but should not limit yourself to, the following:

adhesives
automobile oil and gas products
grease and rust solvents
pesticides
nail polish and nail polish removers
bleach
ammonia
drain openers
fungicides and wood preservatives
oven cleaners
lighter fluids
flea collars and shampoos
spot removers
laundry detergents
batteries
paint stripper and thinners
wood and metal cleaners
paints
wood and metal polishers
antifreeze
aerosol cans

CONTINUED ▸

② For each hazardous product you find, note the major hazard indicated on the label and count the number of cans or bottles found. **Record** your findings in a clearly labelled data table or chart. Use the following categories as headings:

(a) paints and solvents
(b) pesticides
(c) household cleaners
(d) automobile products
(e) other

③ Ensure the product is safely stored before you search for the next one.

Analyze

1. Which of the five categories contained the most household hazardous products found in your home?
2. Construct a bar graph illustrating your totals in each of the areas (a) to (e) as compared to the class average.
3. Would you expect every student in the class to have obtained similar results to yours? Explain your answer.
4. Based on your survey, what hazard category did most containers fall under — Dangerous, Poisonous, Flammable, Explosive, or Toxic?

Conclude and Apply

5. How safely stored were the hazardous products you identified? What are the consequences of incorrect storage of those products?

Part 2

Question

What are the hazards involved in use and storage of paints and adhesives?

Procedure

① Carefully study the label on one of the paints or adhesives that you found during your survey of your household hazardous wastes. Is the solvent used in that product listed by name? If it is, **record** the name. If the solvent is not listed, **record** the name of the product, the name and address of the manufacturer, and any contact information supplied (e-mail address, web site, telephone number).

② If the solvent is not listed on the label, contact the manufacturer and request an MSDS sheet for that product. This will allow you to proceed to step 3.

③ After determining the name of the solvent in the chosen product, search the Internet for any information about that solvent. You should be able to describe:

- what the solvent is
- what happens to the solvent when it enters the environment
- likely methods of exposure
- how that solvent can affect your health
- how you might medically determine whether you have been exposed or not

If possible, also try to obtain the LD50 information relating to that solvent. The Agency for Toxic Substances and Disease Registry (ATSDR) is a good place to start.

④ Prepare a one-page poster that summarizes the information you obtained in step 3.

Analyze

1. Why is exposure to paint (oil-based or water-based) likely to cause health problems?
2. Why should you avoid contact with solvent-based adhesives?
3. How easy was it for you to obtain information relative to the actual risks and actual toxic effects of the solvent that you investigated? Are there any reasons to explain the ease or difficulty of your task?

Waste Management — Back to the 4 Rs

Garbage is any material for which we no longer have a use — old paper, plastic, food scraps, tin cans, glass bottles, used motor oil, motors — you name it! Fortunately, we no longer consider surplus pesticides or cleaning products to be garbage but hazardous wastes. However, whether garbage or hazardous waste, we still have the problem of disposing of it.

The environmental movement involves four principles — the 4 R's: Reduce, Reuse, Recycle, and Recover. Reduce is the preferred option of the four, because it has the most potential to change things. If goods are not manufactured in the first place, then not only will they not be present to be discarded but there will be a saving of the materials and energy needed to make those goods. Lower costs are a direct result. Reuse and recycle are a good second option. One person's "trash" is, from another viewpoint, someone else's untapped resource. Paper waste forms one quarter of the mass of municipal garbage and almost all of it can be recycled. Glass and metals account for a total of about 8 percent, and plastics about 6 percent of the wastes we generate. Of course not all of the glass, metals, or plastics can be recycled, but at least some of it can be. Yard wastes (about 20 percent) and food wastes (about 9 percent) are usually biodegradable, thus reducing the quantity of waste even more. So why do we need landfills?

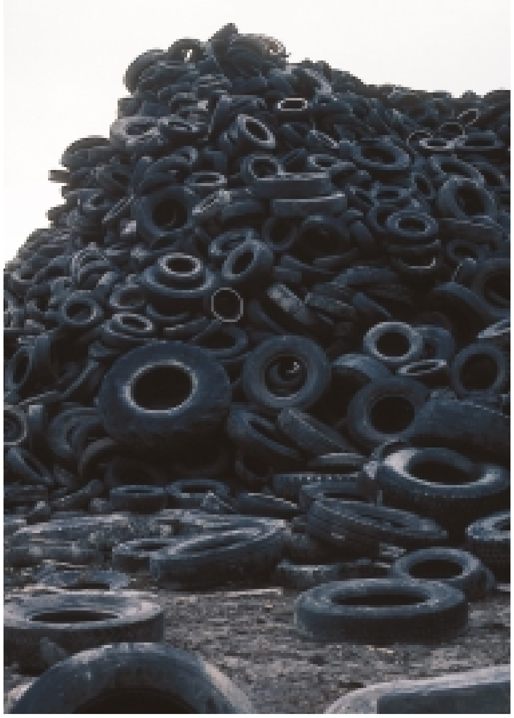


Figure 3.32 Old tires don't decay and are almost indestructible. The high temperatures needed to break them down may result in toxic emissions, so dumping in landfills has been the traditional solution.

Math CONNECT

The average Canadian generates an average of 2 kg of unwanted materials per day. The population of Canada is about 30 500 000. Find out the current population of your province. Then calculate the amount of unwanted materials generated per day in your province and in Canada. If 1 kg of trash takes up 0.004 m^3 of space, how tall would a column of the trash produced by your province be, if the column's base had an area of 1 m^2? (The Calgary Tower is 190 m tall. How would the pile of trash compare?)

Although recycling does incur costs for transporting, handling, sorting, cleaning, and storing, it nonetheless has many advantages. For example, the production of recycled paper requires 58 percent less water and generates 74 percent less air pollution than when paper is made from trees.

Recycling one single aluminum can saves enough energy to run a television set for 3 h. The energy needed to make one brand-new can from aluminum ore is enough to recycle 20 aluminum cans. Recycling conserves resources, but recycling is a voluntary activity. How might municipalities encourage more people to recycle?

DidYouKnow?

Edmonton's Waste Management Centre enables the city to divert 70 percent of its residential wastes away from landfill. The facility is one of the largest of its kind in North America and complements coexisting recycling programs by separating recyclable materials from compostable materials. Organic wastes — including paper and cardboard that are not able to be recycled — are mixed with sewage sludge from the city's waste water-treatment plant. Slow mixing occurs over one to three days in giant drums, 74 m long and 4.9 m in diameter. After mixing, the material is screened to remove non-biodegradable materials and then sent to aeration bays for optimum composting. State-of-the-art odour-control systems capture, cool, scrub, and biofilter the air from the entire facility before venting to the outside environment.

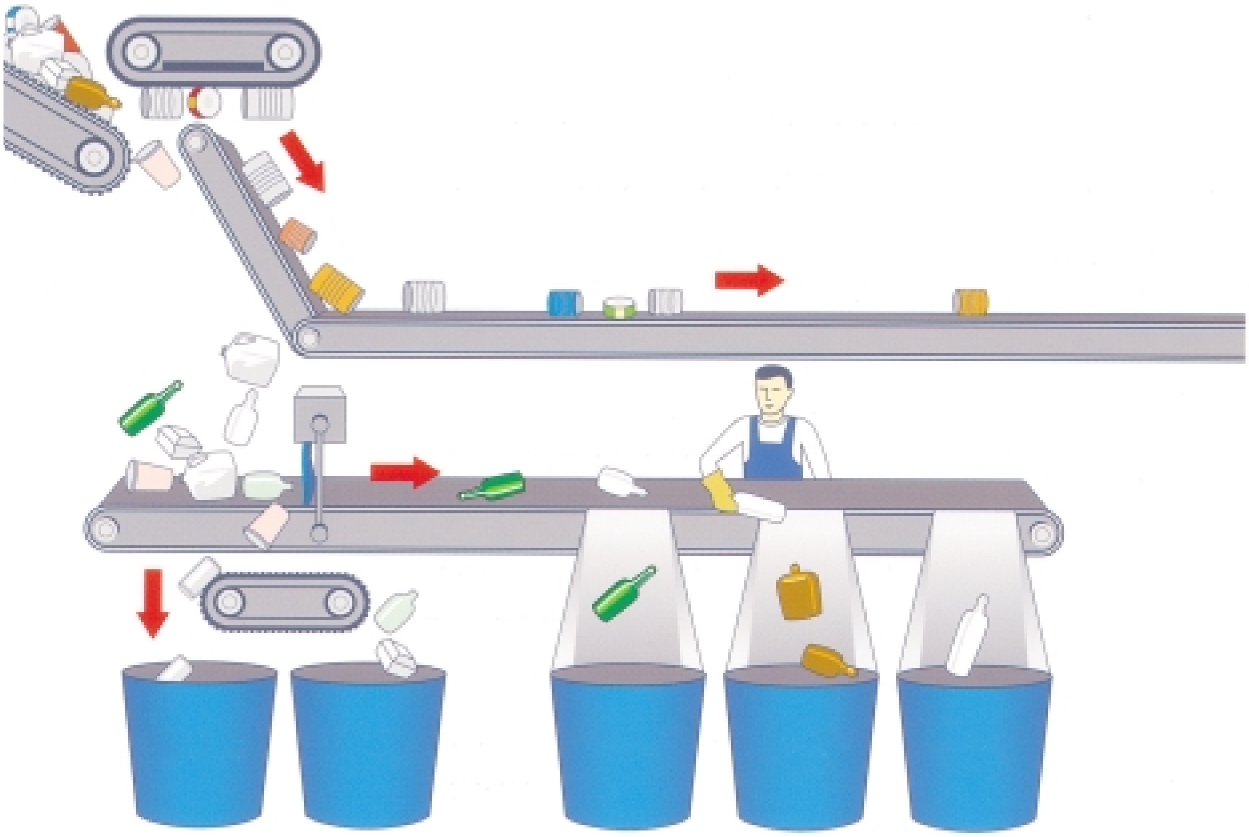


Figure 3.33 Recyclable materials first go to a material recovery facility, where they are sorted mechanically and manually. Glass is separated by colour — amber, green, or colourless. Plastics are sorted by type.

Landfill Construction and Design

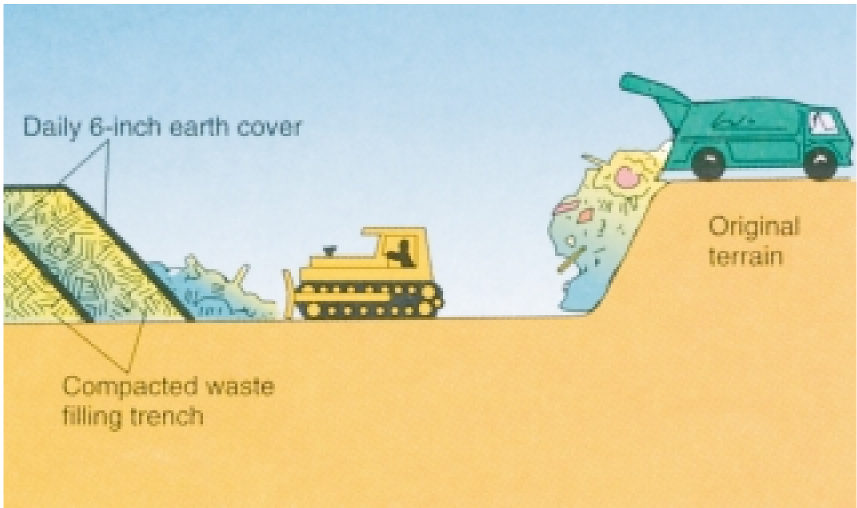


Figure 3.34 In a sanitary landfill, trash and garbage are crushed and covered each day to prevent accumulation of vermin and spread of disease. A waterproof lining is now required to prevent leaching of chemicals into ground water.

Despite the best efforts of even the most aggressive recycling campaign, a considerable amount of material needs to be dumped in a landfill. In the absence of efficient recycling, the garbage that reaches a landfill is almost 60 percent organic. The increased noise, traffic, and mess associated with daily operation of a typical landfill are some of the concerns that lead to a N.I.M.B.Y. response. A sanitary landfill is one short-term solution. As you can see in Figure 3.34, much of the garbage in a **sanitary landfill** is covered each day to avoid windblown litter and attracting scavengers. Most modern sanitary landfills incorporate a clay liner (and some add a plastic liner) that prevents fluids from filtering down into ground water supplies. **Leachate**, the liquid that results as wastes decompose and rainwater filters down through the landfill, is collected and sent to waste water-treatment centres. The anaerobic conditions created by burying organic waste results in the production of methane and carbon dioxide. Methane will filter up to the surface and cause safety problems due to the risk of explosion. At many landfills, methane is piped to the surface and burned or "flared off" in a controlled manner.

STRETCH Your Mind

Disposable diapers account for almost 2 percent of the total volume of our landfills. This may sound like a lot of diapers, and it is, but then you need to consider that most parents change anywhere from 5000 to 10 000 diapers per child. Critics of the use of disposable diapers point out that such diapers are made from mostly synthetic materials, require vast amounts of energy to produce, and are really not very biodegradable, so they will last almost forever in a landfill. Industry representatives are quick to point out that growing the cotton for cloth diapers uses vast amounts of pesticides and chemical fertilizers, and the washing of cloth diapers requires large amounts of energy, disinfectants, detergents, and water. So which method, cloth or disposable, would you use as an ecologically conscious parent? It's your choice.

DidYouKnow?

At Edmonton's Waste Management Centre, the production of methane gas by decomposing garbage in the Clover Bar landfill is fully exploited. Over 100 wells have been sunk deep into the landfill. The methane gas is withdrawn, purified, and shipped by pipeline to the nearby Clover Bar Generating Station, where it is burned to create electricity. At maximum capacity this process provides enough gas to meet the electricity requirements of 3600 houses, and the City receives royalties of between $30 000 and $75 000 per year, depending on how much is captured.

The City of Edmonton uses methane gas from its landfill to produce electricity for residental use.

Secure Landfills

Hazardous and toxic wastes represent a different sort of challenge. They must be disposed of in specific ways. **Secure landfills** use the same clay liner system as other landfills, but it is overlaid with a layer of gravel, a grid of perforated drain pipes to collect any seepage, and a final thick plastic liner backed by soft padding. Sand cushions the plastic liner from the drums of waste, which are stacked into the landfill. Thick layers and walls of soil separate the drums if seepage occurs. When full, the landfill is capped by clay, plastic, and soil. Wells are drilled outside the site to monitor any possible leakage from the site.

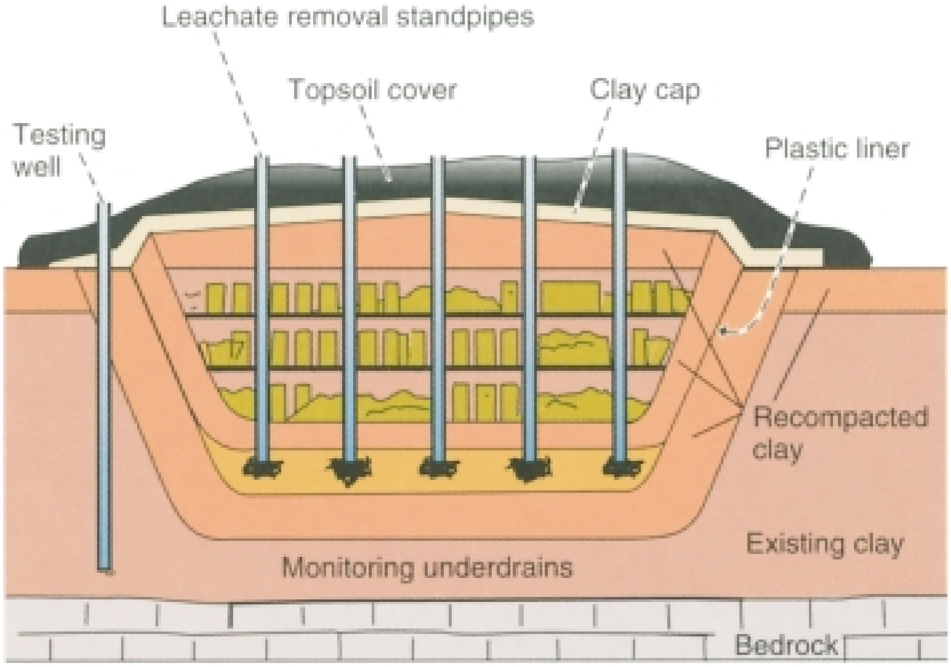


Figure 3.35 A secure landfill for toxic waste. Contents are enclosed by a thick plastic liner and two or more layers of impervious compacted clay. A gravel bed between the clay layers collects any leachate, which can then be pumped out and treated. Testing wells sample for escaping contaminants.

DidYouKnow?

At the Swan Hills Treatment Centre, hazardous and toxic wastes are destroyed by incinerators that operate at 1200°C. The oxide gases and particles produced by these extreme temperatures are passed through a scrubbing system, and the residue is stabilized. Inorganic solid wastes that aren't reduced by incineration methods are treated chemically and physically to form stable compounds. Liquid inorganic wastes are chemically reduced and neutralized, then filtered to remove solids that form. Those solids are stabilized to an inert compound. All solids formed in treatment are deposited in a secure landfill, and any liquids are treated, then injected into a stable rock formation almost 2 km below the surface.

Find Out ACTIVITY

Garbage In, Garbage Out?

When garbage is put into landfills, it is covered under other trash and soil and isn't exposed to sunlight and other things that help decomposition. When examined by a researcher, one landfill was found to contain grass clippings that were still green and bread that had not moulded.

In this activity, you will make a model of a sanitary landfill and compare and contrast the decomposition of different materials in a landfill.

Safety Precautions

- Be especially careful not to expose your skin or eyes to garbage items.

Materials

scissors
2 2L plastic bottles
soil
thermometer
plastic wrap
graph paper
rubber band
trash (including fruit and vegetable scraps,
a plastic item, a metal item, a foam cup,
and notebook paper or newsprint)

Procedure ✷ Performing and Recording

1. Cut off the tops of two 2 L bottles.
2. Add soil to each bottle until it is half filled.
3. On graph paper, trace the outline of all the garbage items that you will place into each bottle. Label each outline and keep them.
4. Place the items, one at a time, in each bottle. Completely cover each item with soil.
5. Add water to your landfill until the soil is slightly moist. Place a thermometer in each bottle and seal the bottle with the plastic wrap and a rubber band. Store one bottle in a cold place and put the other on a shelf.
6. Check the temperature of your landfill on the shelf each day for two weeks. Record the temperatures in a data table that you design.
7. After two weeks, remove all of the items from the soil in both bottles. Trace the outlines of each on a new sheet of graph paper. Compare the sizes of the items with their original sizes.
8. Be sure to dispose of each item properly as instructed by your teacher. When you have completed the investigation, remove your gloves and wash your hands thoroughly.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Most decomposition in a landfill is due to the activity of micro-organisms. The organisms can live only under certain temperature and moisture conditions.

   Explain how the decomposition rates would have differed if the soil had been completely dry.
2. Compare your results with the results from the bottle that was stored at a cold temperature. Explain the differences you observe.
3. Why do some items decompose more rapidly than others?
4. What problems are created in landfills by plastics?

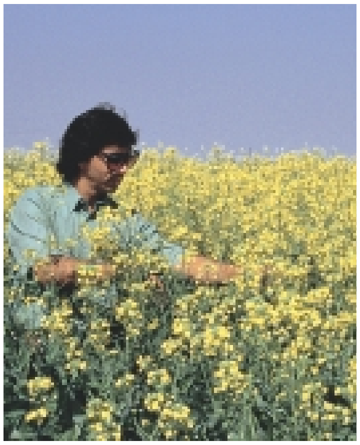


Figure 3.36 Mustard plants

Bioremediation — Mother Nature to the Rescue

You have already seen how water hyacinths can help remove pollutants at waste water treatment centres. Plants tend to take in pollutants through their roots and either concentrate and store those pollutants, or in many cases change those pollutants to less noxious forms. Mustard, fescue grass, and the familiar poplar tree are examples of plants that reduce hazardous substances to less harmful forms. Mustard and fescue grass (shown in Figures 3.36 and 3.37) are currently being used to remove selenium metals from contaminated soils left by irrigation. This method of using living organisms to fix a problem is referred to as **bioremediation**, and is a cheap and effective alternative to other methods of waste treatment.

The discovery of bacterial species that can attack and break down some of the more persistent and toxic wastes is yet another method of bioremediation. Normally these bacteria have very limited range, a result of the extreme conditions where they live. Some exist only at high temperatures and/or pressures. Some are able to survive only in extremely acidic or anaerobic conditions. Container tanks called **bioreactors** house these bacteria in appropriate conditions where contaminated ground water is pumped in and the bacteria are encouraged to go to work. Who knows? In a few years we may be able to eliminate the need for landfills completely.

Figure 3.37 Fescue grass

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To find information about the Environmental Protection Agency's Citizen's Guide to Phytoremediation. Go to the web site above, and click on Web Links to find out where to go next. In your notebook, write a paragraph or two presenting your opinion on this issue.

TOPIC 6 Review

1. Why is it that although we are no longer producing chlorofluorocarbons (CFCs), the ozone layer is still being destroyed?
2. What are the main steps in sewage treatment? Describe the purpose of each step and the overall purpose of sewage treatment.
3. What is the difference between ground water and surface water?
4. What makes a waste a hazardous waste? List five hazardous wastes around your home and describe how you would dispose of them.
5. **Apply** There are 15 fewer trees cut down for every 1200 kg of paper recycled. For a large city, 150 000 kg of paper are recycled every month. How many trees are saved every year due to recycling?

Wrap-up TOPICS 4-6

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

pollutant
pollution
toxicity
acute toxicity
chronic toxicity
LD50
non-persistent wastes
persistent wastes
biological indicator
macroinvertebrate
point source
non-point source
ground water
aquifer
biodegradable
hazardous
solvent
sanitary landfill
leachate
secure landfill
bioremediation
bioreactor

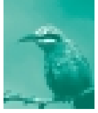
Reviewing Key Terms

1. Explain the term "pollution." (4)
2. Explain the phrase "the danger is in the dose." (4)
3. Why is the toxicity of a substance expressed as an LD50 measurement? (4)
4. What makes the macroinvertebrates such a good biological indicator species? (5)
5. Why is it worse to have a point source discharge into ground water than it is to have it discharge into surface water? (5)
6. Why do most glues come with warnings about avoiding skin contact and the importance of keeping the lid on the container when not being used? (6)

Understanding Key Concepts

7. Explain how heated water that is discharged by a power plant can be a pollutant. (4)
8. Describe how excess agricultural run-off in the spring leads to a decrease in the number of stonefly and dragonfly larvae downstream of where the run-off enters the water. (5)
9. The young western gull in the picture is unable to remove the plastic six-pack holder tangled around its head. Recycling reduces litter and may have prevented this unfortunate occurrence. Describe three other reasons why recycling is beneficial to the environment. (6)

10. Describe the differences between a sanitary and a secure landfill. What is it about a landfill that makes it "sanitary"? (6)
11. You may be surprised to find that fluorescent light bulbs are classified as hazardous wastes. Investigate and explain why this is so. (6)
12. Many small coastal towns and cities extend sewage pipes out into the ocean and release untreated sewage directly into the seawater. What two mechanisms might be acting to reduce or prevent this from being a severe case of pollution? (6)



Ask an Expert

After graduating from the Chemical Technology Program at NAIT, Heather Sumner put her interest in science and the environment to work. She started in a laboratory as a chemical technologist analyzing samples. She then moved to the field as an environmental consultant at Green Plan Ltd. in Edmonton, where Heather has worked on many projects and offered her nine years' experience to businesses and the government to help make Alberta a cleaner place to live and work.

Q **How did you turn your love of science into a career as an environmental consultant?**

A I started working in an environmental laboratory and became familiar with that aspect of environmental chemistry — working with soil and water samples from various monitoring programs. Then I decided to do something different. I worked for an environmental sampling equipment supplier for about a year and that is where I was introduced to environmental consulting.

Q **Has your experience in both the laboratory and the field been beneficial to you?**

A Yes, definitely. Working for both sides has been helpful because now that I am submitting samples to the lab, I understand what the technologists require in order to get the best results.

Q **What does an environmental consultant do?**

A We prepare different types of assessments and reports for clients, depending on what they need. Basically, it starts with us looking at the historical background and use of a property. Then we determine if there is a need to collect any soil or water samples from it. If we find that there is some contamination, the next step is to find out how much and where it ends. Lastly, we determine how to do remediation and clean-up.

Q **How do you collect samples?**

A To collect soil samples, I use hand augers or core samplers. We may hire a licensed driller if there is going to be lots of test holes. Also, past a depth of a metre or two, we have to get the heavy-duty equipment to drill down that far. For water samples, we have a licensed drilling contractor install ground water-monitoring wells, and then we use bailers to collect samples.

Q **Is your job finished once you collect the samples?**

A No. Once I collect the samples and get the results back, I generally prepare a report for my client, detailing the work I've done, the methods I used, the lab results, and an interpretation of the results.

Q **Is the report shared with a government body?**

A Reports have to be submitted to Alberta Environment so that they are aware of the issue on the property. They keep records about the property and can take steps to ensure that any contamination is cleaned up.

Q **For what are the samples analyzed?**

A There are many things. Samples can be tested for heavy metals, hydrocarbons such as gasoline and diesel fuels, or salt contamination. It runs the gamut, but those are what I have been exposed to since I've been consulting.

Q **What do you enjoy most about your job?**

A I do a lot of work outdoors. I am lucky because I have a balance between indoor and outdoor work. If I am not in the field, I am in the office writing reports. It is fascinating. You can have a manual or training, but that doesn't always work in the field. There are always different situations that you have to adapt to.

EXPLORING Further

Supercritical, Super-Useful

Once environmental chemists like Heather Sumner have identified contamination in soil, environmental companies use a form of carbon dioxide to clean it. The carbon dioxide is brought up to a certain pressure and temperature. In that state it becomes a supercritical fluid. It behaves a little like a liquid and a little like a gas.

Use your local library to find out more about supercritical fluids and the research that is being carried out with them around the world. As a starting point, go to
www.mcgraw.ca/links/sciencefocus9

An *Issue* to Analyze

A SIMULATION

Not in My Backyard

Think About It

Ammonia (NH_3) is a colourless, pungent gas at room temperature. One of its compounds, ammonium nitrate is used to make fertilizers and explosives.

Commercially, ammonia is produced by reacting nitrogen with hydrogen at high temperatures and pressures. The hydrogen for this reaction is purchased from industries that use hydrocarbons. Thus ammonia plants are near petrochemical plants.

Suppose that you live in a small, rural community that has grown up around a petrochemical plant. The president of a new chemical company wants to build a chemical plant nearby. This plant will process ammonia to produce fertilizer and precursors for explosives. The president assures the Town Council that the plant will not manufacture the explosives. The company will purchase land near the edge of town, very close to a marsh that is a nesting area for wetland birds such as cormorants, ducks, bitterns, and red-winged blackbirds.

The company expects to employ up to 150 local residents, mostly for manufacturing jobs. There will also be openings for engineers and chemists. Local farmers expect to benefit from reduced fertilizer costs. Some townspeople, however, are concerned about the consequences for the environment and human health, especially the effects of fumes, gaseous emissions, and potential spills.

The plant will be equipped with pollution-control technologies. As well, every effort will be made to minimize spills and leaks. The proposal includes an action plan, explaining what to do if a spill or leak does occur. This action plan will be delivered to every home.

A town-hall meeting is scheduled for next week so people can ask questions and voice their concerns at this meeting.

Plan and Act

1. The following people have submitted requests to make formal presentations at the meeting:
   - an area farmer
   - a member of an environmental advocacy group
   - a chemist who lives in the community
   - a town resident who has a respiratory illness
2. The following company representatives will also speak at the meeting:
   - the president of the company
   - the architect who will design the plant
   - a chemical engineer
3. As a class, discuss the information presented in Think About It. Clearly identify the issue faced by the community.
4. Your teacher will give your group the role of one of the people making presentations at the meeting. As a group, discuss the point of view you are likely to hold in your role. Think about the kind of information you will be expected to supply to others and how you will obtain that information. How could you persuade others to your point of view? If in your role you are in favour of the plant, what alternatives might you present that will lessen the risks people anticipate or increase the benefits? If in your role you are against the plant, what alternatives could you present?
5. As a class, your task is to assess the alternatives that are presented at the meeting and to ensure that the consequences of each alternative have been explained clearly so that you can assess the risks and benefits of the new chemical company. You will then recommend to the mayor (your teacher or another person) whether the application for the new company should be accepted or rejected.
6. When the Town Council has made its decision, go back to your group and evaluate the decision on the basis of all that you have learned. If it is a good decision, you may decide to vote for the plant as a community. If you feel that there were some faulty steps in the above process, you may wish to repeat it.

How Can Science Help?

With your group, write down some of the ways that science could help you examine and assess this issue thoroughly, find and evaluate alternatives, and come to a decision. You might want to monitor the area now for environmental and human health and obtain the plant's forecasts for how this is expected to change and how any harm can be mitigated. You will need to decide what data you require and the most efficient way to collect and record it. You might want to set up a comparison study with another community with a similar plant to find out if spills and leaks have occurred and what kinds of remediation were undertaken, with what level of success. Be as thorough as you can in preparing this part of the task. The better informed you are and the more concrete information you can provide, the better equipped you will be to discuss the issue and to develop alternatives that will help to resolve the issue.

Analyze

1. Compare the presentations on the basis of their scientific soundness, logic, and passion.
2. In what ways did your understanding of science and technology help you in this project?

UNIT 3 Review

Unit at a Glance

- Nutrients are compounds or elements that are essential for production of the organic matter that makes up living organisms.
- Organic nutrients are carbon-based compounds such as carbohydrates, proteins, lipids, and vitamins, which are produced by green plants and modified by animals.
- Inorganic nutrients — the minerals — are divided into macrominerals and trace elements, depending on how much is needed for normal health.
- Minerals are essential components of enzymes and vitamins, the molecules that help regulate the chemical reactions in living organisms.
- Artificial fertilizers greatly increase the amount and types of plant crops that can be grown for human consumption, but also require large amounts of fresh water.
- Agriculture influences the environment by effectively decreasing biodiversity.
- The use of chemical poisons and toxins to control pests is widespread and although they are effective in reducing disease-causing organisms, they should be carefully controlled and regulated.
- Fossil fuel combustion results in the emission of nitrogen, sulfur, and carbon oxides that react with moisture in the atmosphere to form acid compounds.

- Acid precipitation results in the leaching of minerals from soils, and damage to living organisms.
- Acid-base neutralization reactions between minerals, such as limestone (calcium carbonate) and acidified waters in lakes and streams, can lead to more neutral pH water.
- The amount or dose of a pollutant that will cause harm is established by observing the effects of the pollutant on living organisms.
- Toxicity is usually expressed in parts per million (ppm) or parts per billion (ppb).
- Since different organisms respond to toxic chemicals in different ways, toxicity is commonly measured by the LD50 — the dose needed to kill 50 percent of the population that it is applied to.
- The monitoring of the levels of pollutants in any ecosystem requires knowledge of how to detect those pollutants or their effects, either by chemical testing or direct observation of biological organisms.
- Biological indicators are organisms whose presence or absence gives clues as to the amount of pollution affecting any ecosystem.
- The dispersal of atmospheric pollutants is affected by global wind patterns. Pollutants may be carried great distances before their effects are felt.
- Biodegradable wastes are those wastes that can be broken down by the action of living organisms. The rate of biodegradability is determined by the chemical structure of the waste material.
- Bioremediation is the use of living organisms, such as plants and bacteria, to control or remove the presence of pollutants from the general environment.

Understanding Key Concepts

1. The elements calcium, phosphorus, and magnesium are all essential to human health. What common role do these elements have in the human body?

2. What is a nutrient?

3. What are the four major classes of organic nutrients? Specify their roles in nutrition.

4. What connection do plants have to the mineral content in our bodies?

5. How do bacteria in the soil help provide nutrients for plants?

6. What are the three main elemental ingredients found in a bag of fertilizer? What are the roles of those ingredients in plant growth?

7. List two potential problems associated with a move to high-yield agricultural methods that rely on fertilizer use and high-yield crop varieties.

8. What are the three main types of pesticides in use? In general, how are they different?

9. Explain why DDT was such an important discovery in the quest to improve human health.

10. Describe why the use of DDT was eventually banned on a global scale.

11. What is the difference between a poison and a toxin? Is it realistic to use the term “toxic” to describe both poisons and toxins?

12. Describe at least two advantages and two disadvantages of using pesticides in agriculture.

13. What are the health benefits of organic farming? What are the disadvantages?

14. What alternatives might there be to the use of pesticides?

15. Which acids are the main cause of acid precipitation? Write their names and formulas. What is the main source of each of these acids?

16. What is the meaning of the symbol pH? How does the acidity of a liquid with a pH of 3.4 compare to one with a pH of 4.4?

17. What are two consequences of acid precipitation falling to the ground in a forest?

18. Why is acid precipitation so dangerous to plants and animals living in water?

19. Which regions of Canada are most affected by acid precipitation? Give two reasons why regions may be affected differently.

20. Why do all new model cars require a catalytic converter attached to the exhaust system? Describe how a catalytic converter operates.

21. Describe the difference between pollution and a pollutant. Is it possible to use the two terms interchangeably?

22. How does the number of exposures before symptoms occur relate to whether a chemical is defined as having acute or chronic toxicity?

23. Why is an LD50 the preferred method for reporting the toxicity of any particular chemical?

24. Using thalidomide as an example, explain the concept of acceptable risk.

25. What is it about a pollutant that makes it non-persistent?

26. Explain why water testing is a focus for many environmental scientists when they are trying to assess the presence of chemical pollutants.

27. Why is the presence of phosphates and nitrates in a water sample a good indicator of a polluted body of water?

28. Why is measuring the level of dissolved oxygen in a pond a good indicator of the state of "cleanliness" of the water in that pond?

29. Describe the effect of a reduction of dissolved oxygen in a water source on the community of organisms living in that water.

30. Why is the presence of macroinvertebrate species a focus for testing the quality of water? List two macroinvertebrate species that are indicative of clean water and two that are indicative of poor water quality.

31. How can lichens provide an early warning system for air pollution?

32. List three non-point sources of pollutants and suggest methods for reducing the emissions from those sources.

33. Why do atmospheric pollutants concentrate at higher latitudes?

34. Identify the location and mechanism by which CFCs cause damage to the environment. What is the significance of this damage to humans?

35. Which common activities are most likely to contribute to surface water pollution? What can you as an individual do to help prevent the presence of those pollutants?

36. Name and describe the three phases of waste water treatment.

37. Define the terms "ground water" and "aquifer." How are these terms connected?

38. List three sources of ground water contamination.

Developing Skills

39. Solanine, a toxin found in green potatoes, has an LD50 of 6.0 ppm. What amount of this toxin would need to be consumed to produce a 50 percent chance of being lethal for a 60 kg person?

40. The data shown below represents the effect of pesticides to control disease-causing pest species. The number of resistant species was obtained by direct measurement and the number of insecticides in use is the closest estimate possible given the wide range of applications and geographic locations.

Year	Number of resistant species	Number of insecticides in use
1938	7	–
1948	14	40
1954	25	60
1957	76	76
1960	137	100
1963	157	115
1965	185	122
1967	224	140
1975	364	182
1978	392	184
1980	432	185

(a) Make a graph of the data, with years on the horizontal (*x*-axis) and number on the vertical (*y*-axis). Use one coloured line to show the number of resistant species, and another coloured line for the number of insecticides in use at that time.

(b) What is the relationship between years and the number of resistant species? Between year and number of insecticides in use?

(c) What do you think is the reason for the difference in the two lines?

(d) A number of authorities have used the data given to justify a ban on the use of chemical insecticides and a switch to more organic methods, such as the use of Bt pesticides (*Bacillus thuringiensis*). In your opinion, is the use of a genetically engineered bacteria a better option than the use of chemical pesticides? Give reasons for your answer.

Problem Solving/Applying

41. Many people believe that zinc lozenges can help relieve symptoms of the common cold (about 13 mg every 2 h). The recommended daily allowance for zinc is 12–25 mg, and some experts warn that as little as 150 mg of zinc can cause copper deficiency. Explain how using zinc lozenges in the dose recommended by some people might lead to symptoms of anemia (low red blood cell count).

42. Your lawn is looking a little unhealthy, so you decide to apply a chemical fertilizer to "perk it up." You find a bag in your garage that is labeled 7-7-15. Is this an appropriate fertilizer for your lawn? Why?

43. In a train derailment, a significant amount of sulfuric acid leaked into a nearby lake, despite efforts to contain the spill. Environmental scientists who investigated the effect of the sulfuric acid on the lake itself found that the pH of the lake was near normal despite the large volume of acid added to the lake. How could this be?

Critical Thinking

44. PCBs (polychlorinated biphenyls) are stable chlorinated hydrocarbon compounds used between 1929 and 1979 primarily as insulators in electrical transformers. PCBs are fat soluble and do not biodegrade. Disposal of old electrical equipment into landfills creates the risk of introducing PCBs to the environment. A proposal is made to build a high-temperature incineration plant near your community to treat PCB wastes from across the province and from other provinces. Give reasons for and against the construction and operation of such a plant.

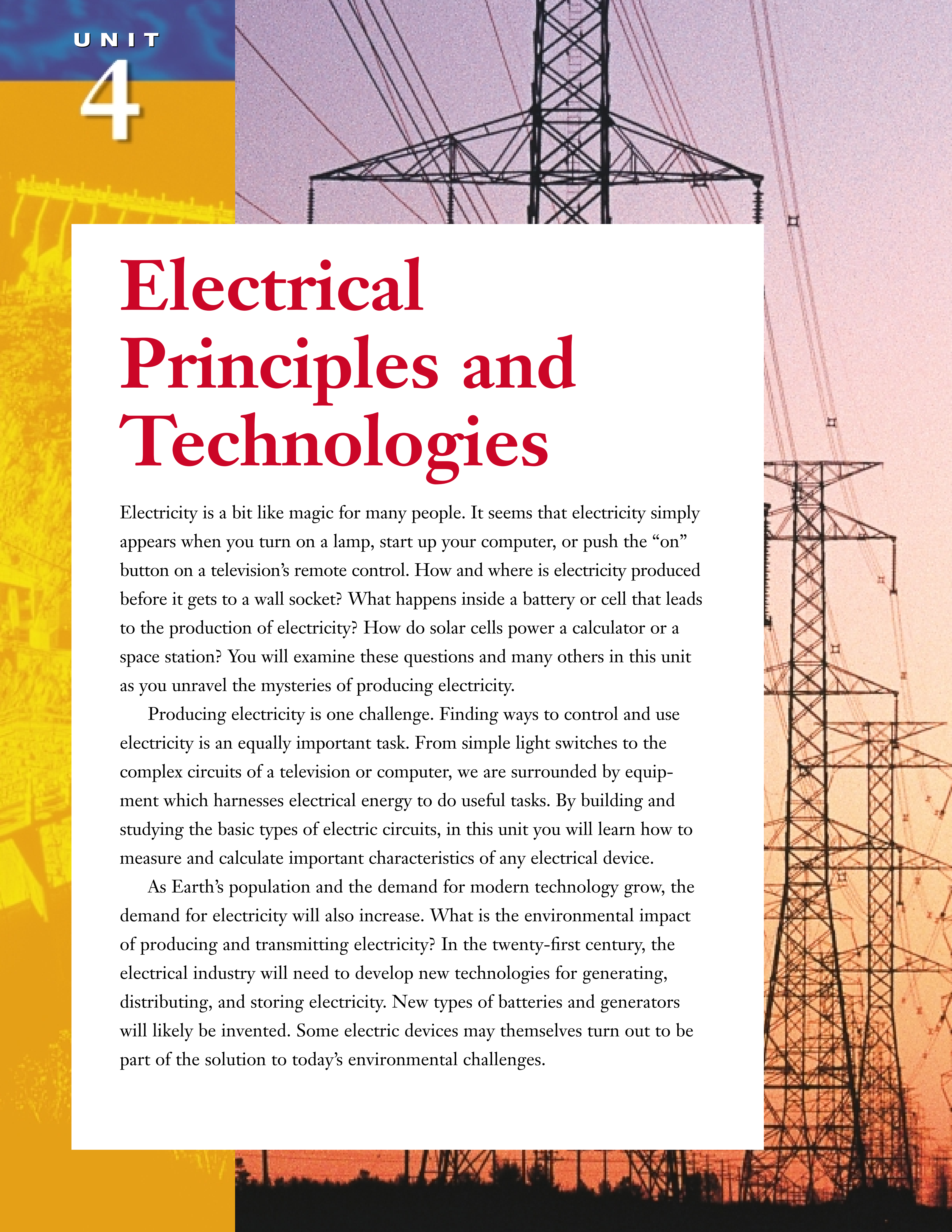
45. Technologies are available to reduce or eliminate acidic emissions caused by human activities. Why is acid precipitation still a serious problem? Why might it increase in the future?

46. Marathon runners who consume large quantities of water during a race run the risk of experiencing a condition called "water intoxication" in which they suffer seizures with symptoms resembling those of epilepsy. Your friend uses this as proof that any chemical is hazardous in excess amounts, but also claims that logically this means that any chemical is also safe if it is in a small enough dose. What is the error in this statement? Explain.

Pause& Reflect

Look back at the Focussing Questions on page 176 and check your original answers to these questions. How would you answer those questions now that you have investigated the Topics in this Unit?

UNIT 4

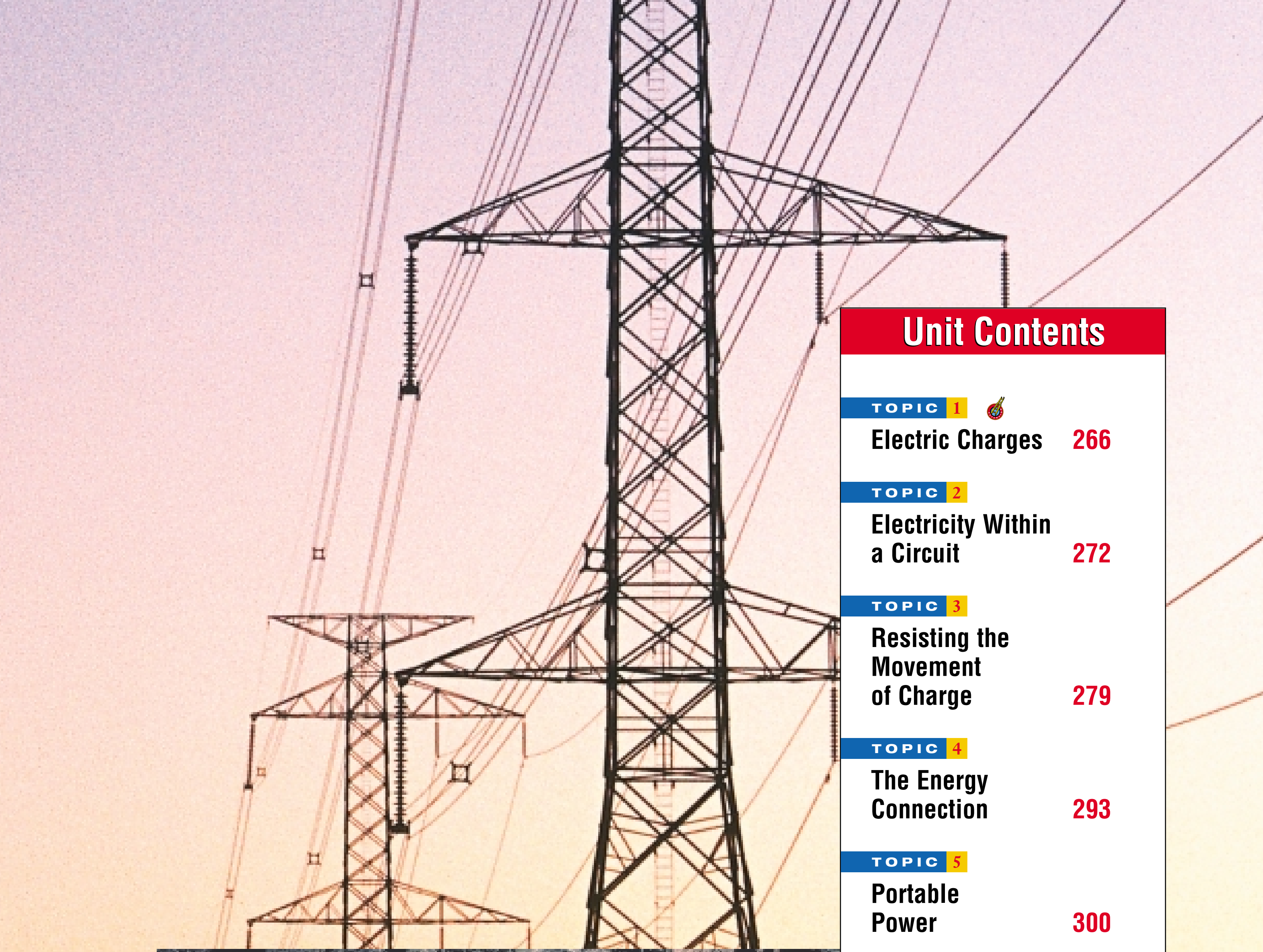


Electrical Principles and Technologies

Electricity is a bit like magic for many people. It seems that electricity simply appears when you turn on a lamp, start up your computer, or push the “on” button on a television’s remote control. How and where is electricity produced before it gets to a wall socket? What happens inside a battery or cell that leads to the production of electricity? How do solar cells power a calculator or a space station? You will examine these questions and many others in this unit as you unravel the mysteries of producing electricity.

Producing electricity is one challenge. Finding ways to control and use electricity is an equally important task. From simple light switches to the complex circuits of a television or computer, we are surrounded by equipment which harnesses electrical energy to do useful tasks. By building and studying the basic types of electric circuits, in this unit you will learn how to measure and calculate important characteristics of any electrical device.

As Earth’s population and the demand for modern technology grow, the demand for electricity will also increase. What is the environmental impact of producing and transmitting electricity? In the twenty-first century, the electrical industry will need to develop new technologies for generating, distributing, and storing electricity. New types of batteries and generators will likely be invented. Some electric devices may themselves turn out to be part of the solution to today’s environmental challenges.



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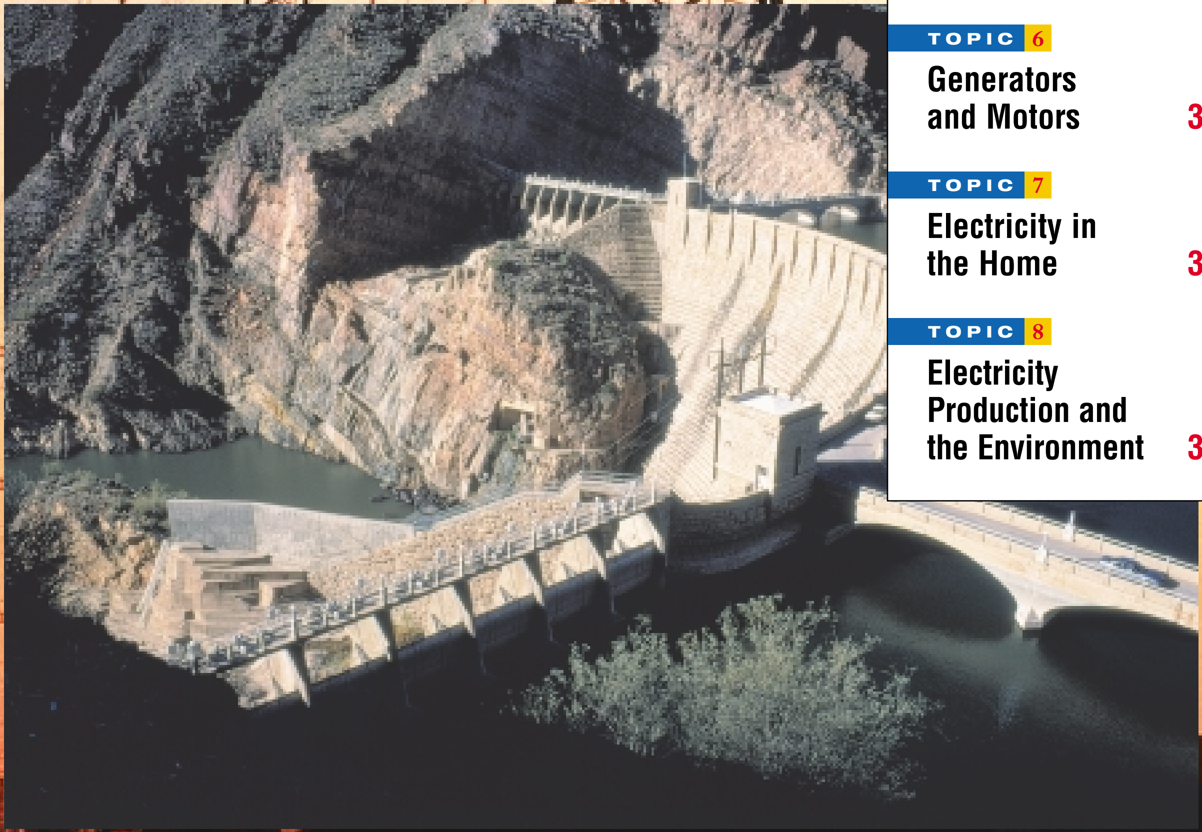
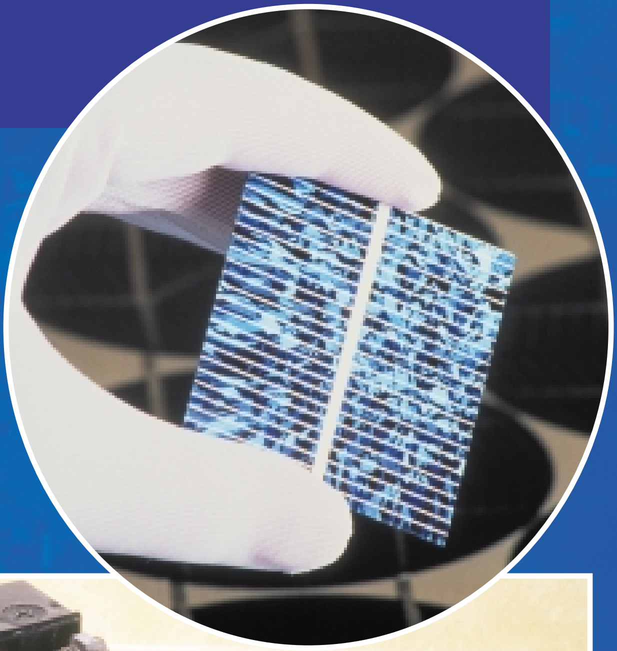


UNIT 4 Preview

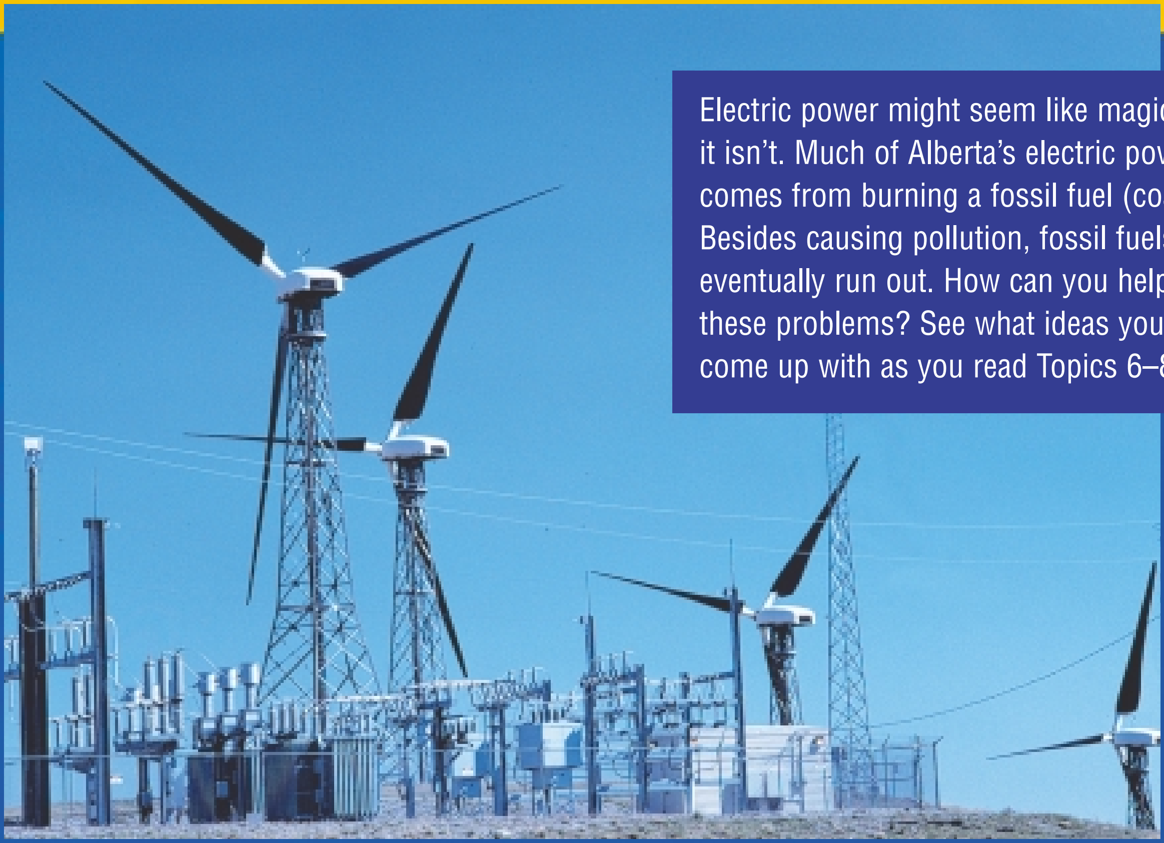
Focussing Questions

- How do we turn coal in the ground or water behind a dam into electric energy that you can use in your home?
- How are we able to control the energy so that the various appliances we use receive just the right amount?
- What new technologies can we develop to help us use energy in less environmentally demanding ways?

Hey presto! Bring an electric charge into existence! Make the charge do some work for you. Now make it stop. And find out when electric charges can be a nuisance for people and machinery. You can do all of these things by reading Topics 1–3.



Is it possible to use chemical energy to produce electricity? Can you produce electricity by using light? And when you've figured out how to do that, can you find a way to store the electricity until you need it? You'll be able to do all of these and more after reading Topics 4–5!

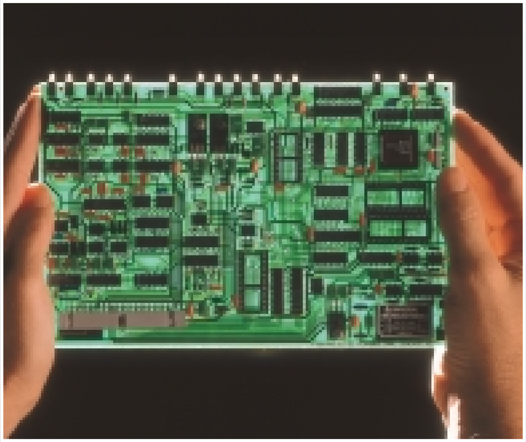


Electric power might seem like magic, but it isn't. Much of Alberta's electric power comes from burning a fossil fuel (coal). Besides causing pollution, fossil fuels will eventually run out. How can you help solve these problems? See what ideas you can come up with as you read Topics 6–8.

Looking Ahead

Look ahead to pages 346–347, My Amazing Electric Invention. In this project, you will work with a group to invent and build your own electric device based on the principles you learned throughout the Topics. As you work through the unit, pay close attention to information about electric devices and components that may help you invent and build your device. You may want to

- draw several designs for possible devices as you learn about loads, circuits, resistors, and other electrical principles
- use a paper or electronic file to keep track of important information that could aid in making your invention work
- discuss your design ideas and knowledge about electricity with your group members



Electric Charges

Storm clouds roll in on a summer evening. Suddenly the sky is split by an enormous lightning bolt, far too energetic to harness or control. By comparison, sparks created when you comb your hair, or the electrical currents created by a battery, are tiny indeed. Scientists have, however, developed a unified explanation for all these phenomena: the idea of electric charge. The electrical devices you use everyday, from lightbulbs to computers, use the energy of moving charges to do useful work. This Topic will introduce you to the theory and laws of electric charge.

Find Out ACTIVITY

Charge It

Many combinations of materials, such as shoes on carpets and clothes in a dryer, will become electrically charged when they are rubbed together. How do charged and uncharged objects react to each other? Can you come up with a set of rules that could describe their behaviour?

Materials

watch glass (at least 10cm diameter)
2 acetate strips (at least 12 cm long)
2 vinyl strips (at least 12 cm long)
1 sheet of paper towel

Procedure

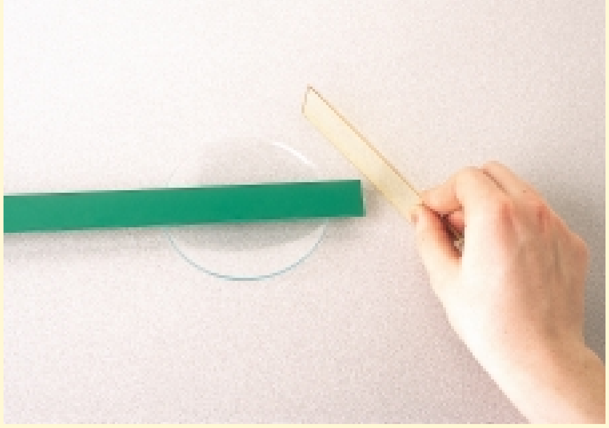
Performing and Recording

1. Copy the observations table and then experiment to complete it.
2. Just before each trial, remove any charges from the watch glass or any "uncharged" strip by gently wiping them with your hand.
3. Charge plastic strips by pulling them gently through a folded paper towel several times.
4. Balance one strip on the watch glass without letting it touch the table or anything else.
5. Move the handheld strip near one end of the balanced strip. Note any movement. If the strips touch, you will need to recharge them.

Trial	Strip balanced on the watch glass	Hand-held strip	Behaviour of balanced strip (attracts, repels, nothing)
1	uncharged acetate	uncharged acetate	
2	uncharged acetate	charged acetate	
3	charged acetate	charged acetate	
4	charged acetate	uncharged vinyl	
5	charged acetate	charged vinyl	
6	charged vinyl	charged vinyl	
7	uncharged vinyl	uncharged vinyl	

What Did You Find Out? ✷ **Analyzing and Interpreting**

1. Describe the behaviour(s) you observed between:
   - (a) two uncharged strips.
   - (b) two charged strips.
2. Were the behaviour(s) between charged strips always the same? Explain either why they were the same, or why they were different.
3. Write three rules that describe the possible behaviours that occur when objects with different charges are brought close to each other.



Producing Charges

Materials that attract and repel other materials are said to be charged, or carry an electric charge. It is these charges that were being collected when you rubbed the plastic strips with paper towel in the Find Out activity. The charge is responsible for the change in the material's characteristics after rubbing or touching. In the Find Out Activity, for example, the plastic strips were able to attract or repel each other if one or both of them became electrically charged.

How are electric charges produced? Many combinations of materials become charged when they are rubbed, touched, or moved close together and then separated. Think, for example, of shuffling across a carpet. Both you and the carpet develop an electric charge. As a result, your body behaves differently when you touch a door handle or another person. You receive an electric shock, and may even notice a spark — a tiny bolt of lightning. In a thunderstorm, water droplets and ice crystals in the clouds are buffeted by the strong winds, colliding and rubbing against each other. When you walk across a room, your shoes or socks rub against the carpet.

Cool Tools

Electric charge can be detected by an instrument called an electroscope. Pocket-sized electroscopes called dosimeters are used to measure exposure to atomic radiation. Charged particles produced by the radiation are detected by the dosimeter. There are strict limits to the amount of radiation exposure that workers may receive.

In many cases, charges produced by rubbing or touching remain stationary, so they are sometimes called **static electricity**. There are, however, many instances when these charges move, so **unbalanced charges** is a more accurate way of describing the phenomenon.

It is difficult to measure electric charge directly. Fortunately, that is seldom necessary, because the amount of charge can usually be calculated from other measurements. The quantity of electric charge is expressed in coulombs (C). A bright light bulb, for example, allows about 1 coulomb of electric charge to pass through it every second.

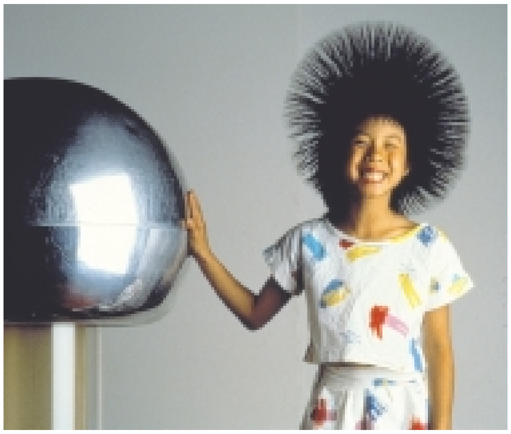
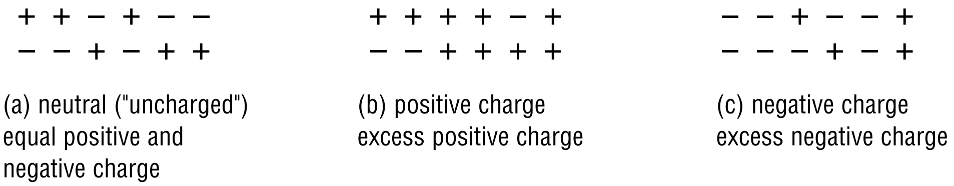


Figure 4.1 A Van de Graaff generator produces large electric charges on a metal sphere. How can you tell that the girl touching the generator has also become electrically charged?

Making Sense of Electric Charges

As you have discovered, charged objects attract neutral objects. Some charged objects repel each other, while others attract each other. There are three interactions to be explained. Scientists explain these interactions in terms of positive and negative charges in the materials themselves.



(a) neutral ("uncharged") equal positive and negative charge

(b) positive charge excess positive charge

(c) negative charge excess negative charge

Figure 4.2 The charge on an object depends on the balance between positive and negative charges in the object.

Pause & Reflect

In your Science Log, explain whether electrons would need to move onto or off an object in order to charge the object negatively. How could an object be charged positively by moving electrons?

American inventor and politician Benjamin Franklin (1706–1790) was the first to use the terms "positive" and "negative" to describe charges. Franklin called the charge on amber that had been rubbed with fur *negative*. The charge left on the fur was called *positive*. Two different charges, one positive and one negative, are called *unlike* charges. Two charges of the same type (both positive or both negative) are called *like* charges. Benjamin Franklin lived before scientists understood that all matter consists of atoms, which in turn contain positively charged particles (protons) and negatively charged particles (electrons). According to modern theory, unbalanced charges on solid materials are due to the movement of electrons from one object to another. Even without this knowledge, however, Franklin's experiments helped establish the **Laws of Charges** that describe the behaviour between charged and uncharged objects.

1. Unlike charges attract.
2. Like charges repel.
3. Charged objects attract uncharged (neutral) objects.

Conductors, Insulators, and In-Between

For many materials, such as rubber, a charge stays on the spot where you rub the object. Such materials fit into a class called **insulators**. Insulators are materials that do not allow charges to move freely on or through them. Materials that allow charges to move freely, are classified as **conductors**. Most metals are conductors and most non-metals are insulators.

Since electrons are the charges that move through solids, a conductor must be a material that holds its electrons loosely. Insulators, on the other hand, are materials that hold their electrons very tightly. Some materials are not perfect insulators, but they are not good conductors either. These "fair conductors" allow electrons to move, but not at all freely. Table 4.1 classifies some common materials by their electrical conductivity.

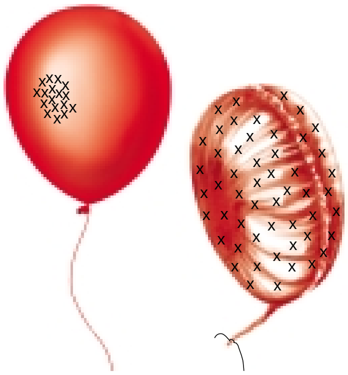


Figure 4.3 When you rub a rubber balloon, the charges (x) remain in place. When you rub a metallic balloon, the metal conductor allows the charges to move freely over the entire surface.

Table 4.1 Some Common Conductors and Insulators

Good Conductors	Fair Conductors	Insulators
aluminum	silicon	cotton
copper	carbon	glass
gold	human body	paper
nickel	humid air	plastic
platinum	nichrome	porcelain
silver	water (salty)	rubber
tungsten		water (pure)

Pause& Reflect

In your Science Log, list several common applications for materials with each type of electrical conductivity. Where would you expect to find good conductors, fair conductors and insulators being used in typical electrical devices like lights, calculators, extension cords, and stoves?

Semiconductors are materials with higher conductivity than insulators but with lower conductivity than metals. Their conductivity is often increased by implanting foreign atoms into the otherwise pure material. Two commonly used semiconductors are silicon with gallium added and germanium with phosphorus added.

Superconductors are materials that offer little, if any, resistance to the flow of charges. Certain materials become superconductors when they are subjected to extremely low temperatures — about –137.15°C to –273.15°C. Superconductors are usually made of metal alloys and ceramics. Some applications of superconductors include components for electric generators, high-voltage power lines, and supercomputers. Superconductors take up less space and can carry higher charges than ordinary conductors. In one power transmission application, about 114 kg of superconducting wire replaced about 8200 kg of copper cable, making it more than 7000% more space efficient.

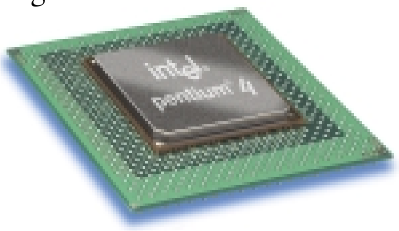


Figure 4.4 Silicon semiconductors are used extensively to make computer microchips.

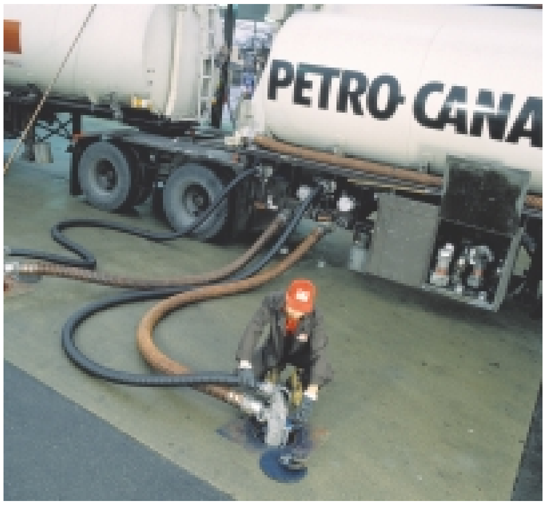


Figure 4.5 When a gasoline truck rolls down the highway through blowing wind and dust and over bumpy roads, it often becomes charged. Before the truck delivers gasoline, it is grounded. This prevents sparking that could cause gasoline fumes to explode. The movement of gasoline through the hose also produces charges, so the grounding cable must remain attached during the delivery, as well as before it starts.

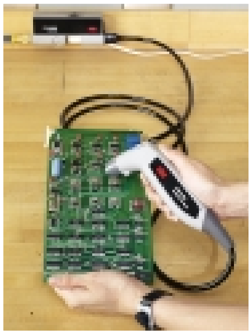


Figure 4.6 Hand-held ionizers can neutralize electrostatic charges on non-conductors.

Figure 4.7 Coatings and sprays are applied to surfaces to prevent buildup of charges and to dissipate charges that are already present.

Neutralizing Unbalanced Charges

Have you ever battled "static cling" when removing clothing from a drier on a dry day? You probably felt, and even saw, small sparks—an electric **discharge**—as accumulated charge on the clothing was **neutralized** (became balanced). Electric discharges are a serious safety hazard, because they can shock people, damage electronic equipment, and cause fires and explosions. Their cause is simple. In a discharge, electrons either enter an object to make up for a shortage, or an excess of electrons leaves the object.

Connecting an object to Earth with a conducting wire — **grounding** the object—is an easy way to neutralize conductive materials. Earth is so large that it can easily supply enough electrons to neutralize a positively charged object. Similarly, Earth can absorb extra electrons from a negatively charged object.

Non-conductors, or insulators, usually must be neutralized with ionization. Ionization devices produce both positive and negative ions. These ions are attracted to materials with an opposite charge, transferring charges until the material is neutralized. Ionizers come in a variety of sizes and shapes ranging from small hand-held devices to large wall-mounted models that are installed in manufacturing facilities.

Preventing Electrostatic Buildup

Buildup of unbalanced charge can be costly, even if there is no electric discharge. Charged objects attract dust and contaminants. They also stick together and jam equipment such as photocopiers. To decrease static buildup, antistatic sprays and coatings can be applied to carpets and other surfaces on which charge accumulates. After materials have become charged, sprays can also be used to dissipate (scatter) the charge (see figure 4.7).

Electronic components like computer memory cards are especially sensitive to electrostatic discharge, so they are often shipped in special antistatic packaging. Before handling sensitive components, electronic technicians may fasten a "grounding strap" on their wrist. The strap contains conductive materials, so that when one end is grounded, any unbalanced charge on the technician's hand or body is neutralized without harmful electric discharge.

Find Out ACTIVITY

Putting Electrostatics to Work

The understanding of how positive and negative charges interact has led to many useful applications for electrostatics.

Materials

poster paper
drawing, writing, and colouring supplies
reference sources, such as the Internet, school library, and resource people

Procedure ✷ Communication and Teamwork

1. Choose a topic that interests you in the field of applications of electrostatics. You might consider electrostatics in painting, farming, negative ion generators, electrostatic precipitators, photocopiers, how electrostatic air filters clean the air in homes and hospitals, how fabric softeners reduce static cling, or how electrostatics is used in studying living cells. Phrase your topic in the form of a question, plan the steps of your research, and discover the answer. Present your information orally to the class, using visual aids, such as posters or a multimedia presentation.

What Did You Find Out?

1. What surprised you about the information you learned in your research?
2. List all the technologies presented by classmates. What additional questions do you have about the applications of electrostatics? List at least three questions you would like to answer.

You have seen how the attraction between positive and negative charges can be harnessed and put to use in a variety of technologies. When the movement of electric charge is controlled within conducting wires, many other fascinating technologies become possible. In Topic 2 you will deepen your understanding of electricity by investigating electric circuits.

TOPIC 1 Review

1. List the three "Laws of Charges." For each law, give an example of the law being applied.
2. Describe the difference between a negatively charged object and a positively charged object.
3. Why is the phrase "unbalanced charges" a more accurate way of describing the phenomena we often refer to as "static electricity"?
4. How do charged conductors and insulators differ from each other? Name two examples of conductors and two examples of insulators.
5. Describe two different ways in which a charged object can be discharged.
6. **Apply** Describe a situation in which electrostatic discharge could pose a problem. Explain how the problem could be solved. Describe an application that uses electrostatic charges in a positive way. Explain how the charges are used.
7. **Thinking Critically** What do you think would happen if you rubbed two identical objects together? Would they attract each other, repel each other, or neither attract nor repel each other? Why?

TOPIC 2 Electricity Within a Circuit

Figure 4.8 Electronic devices often contain hundreds of parts, connected in carefully designed circuits.

Have you ever looked inside a computer or television? Electronic devices, especially older ones, are a maze of mysterious parts connected by a tangle of different coloured wires. No matter how simple or complex, however, every electric **circuit** provides a continuous pathway for charges to move. In the next activity, you can experiment with a very simple circuit, and find out how the energy of moving charges can be harnessed.

Find Out ACTIVITY

Light That Bulb?

In past studies you may have experimented with wires, bulbs, switches, and cells in order to come up with an arrangement that will light the bulb. What requirements must the circuit meet? What role does each component play in a simple circuit?

Materials

2 D-cells (without holders)
4 copper wires (with alligator clips)
1 knife switch
1 3.7 V bulb (without holder)

Safety Precautions

Procedure ✷ Performing and Recording

1. Arrange and connect all of the supplied components so the bulb lights. Draw a simple sketch that illustrates how you constructed your circuit.

2. Arrange all of the supplied materials in at least four additional different configurations that also allow the bulb to light. Make and sketch at least one circuit design with:
   - **(a)** the switch at a different location.
   - **(b)** the cells in a different location or alignment.
   - **(c)** the bulb connected in a different manner.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Describe all of the requirements that a circuit must meet in order to light the bulb.

2. List at least three possible explanations for a situation in which the bulb did not glow.

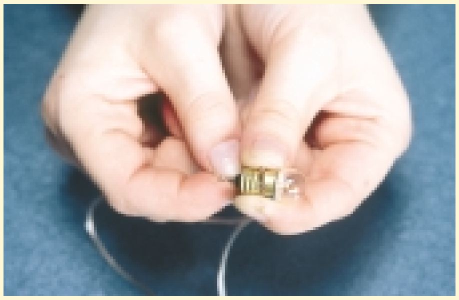
3. Does electricity have to travel through the bulb in a particular direction in order for it to glow? Give evidence from this activity that supports your answer.

4. What role does the switch play in the circuit? How does it carry out this role?

Extension

Study the rules on the next page for drawing a proper circuit diagram. Using this information draw a diagram of a working circuit that includes two cells, two bulbs, and a switch that controls

(a) both bulbs.
(b) only one of the 2 bulbs



Circuit Elements and Diagrams

Even the most complex circuits are made up of only four basic elements, or types of components (Figure 4.9).

- *Source:* The source of electric energy.
- *Conductor:* The wire through which current flows.
- *Load:* Items along the circuit that convert electricity into other forms of energy (for example, light bulbs, motors, heaters, and speakers).
- *Control:* A switch or device that can turn the circuit or devices along it on or off.

Pause & Reflect

Make a table in your Science Log to record the symbols and names of circuit components. Record the symbols in Figure 4.9. Leave room to add to your list as you learn more symbols in your study of electric circuits.

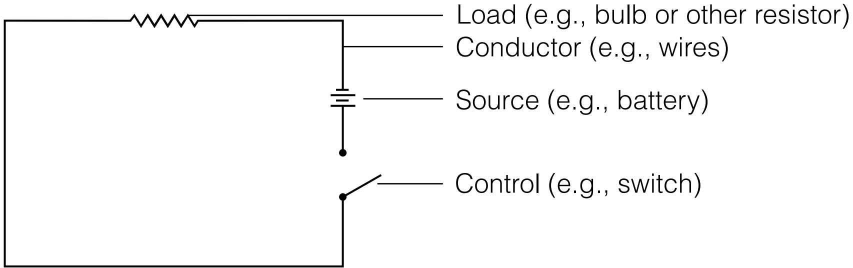


Figure 4.9 Basic components of electric circuits.

You have worked with three laboratory components of an electric circuit: a dry cell, a lamp or light bulb, and a conducting wire. Figure 4.10 shows the circuit symbols for these three components and for several other components.

The cell symbol stands for a single dry cell or a wet cell (you will study wet cells later in this unit). A **battery** is a combination of cells. You can use a **switch** to "open" or "close" a circuit to control the current through it. The **resistor** symbol is used to represent one of many different **loads**. One load is used so much in laboratory work that it has its own symbol: the lamp. Circuit diagrams are drawn in a standard way designed to make them simple and easy to prepare and read. Your circuit diagrams should meet the following criteria.

- Draw with a pencil and ruler on graph paper or unlined pages.
- Place components in a rectangular or square arrangement.
- Make conductors straight lines with right-angled ("square") corners.
- If possible, arrange your diagram so conductors do not cross.
- Draw neatly, making symbols a consistent size.

Word Connect

The term "battery" describes two or more cells connected together. D, C, AA, and AAA "batteries" are more accurately called cells. Car batteries, large 6 V flashlight batteries, and small rectangular 9 V batteries are all correctly labelled as batteries since they contain more than one cell.

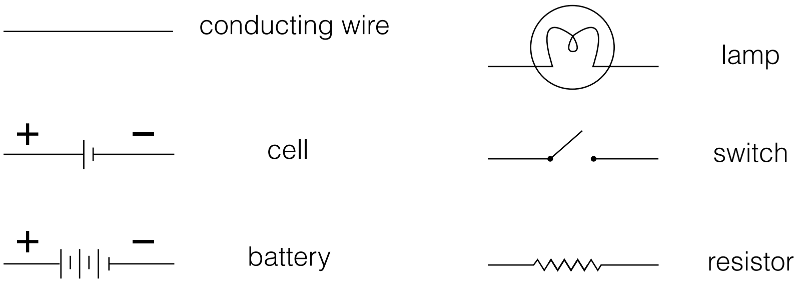


Figure 4.10 Circuit symbols are similar to words; they make communication quick and accurate.

Measuring Current

Imagine a fast-flowing river. If you were to describe the current you might state the number of litres of water that flow past a certain point every minute. Similarly, scientists describe electric current as the amount of charge that passes a point in a conducting wire every second. The symbol for current is *I*. Electric current is measured in **amperes** (A) or milliamperes (mA) (see Table 4.2). Currents in common electric devices range from a few milliamperes to dozens of amperes (see Table 4.3).

Table 4.2 Symbols and Units for Current

Quantity	Symbol	Unit
Current	*I*	ampere (A) milliampere (mA)
Time	*t*	second (s)

Table 4.3 Current in Household Appliances

Appliance	Current (A)
radio	0.4
100 W lamp	0.8
colour television	1.7
toaster	8.8
microwave oven	11.7
electric kettle	12.5
electric range	40

An instrument used to measure very weak electric current is called a **galvanometer**. Larger currents are measured with an **ammeter** or milliammeter. Figure 4.11 shows typical laboratory models of these instruments. The symbols for these instruments are a circle with "G," "A," or "mA" in the centre, respectively. You will use current and ammeters in the next investigation.

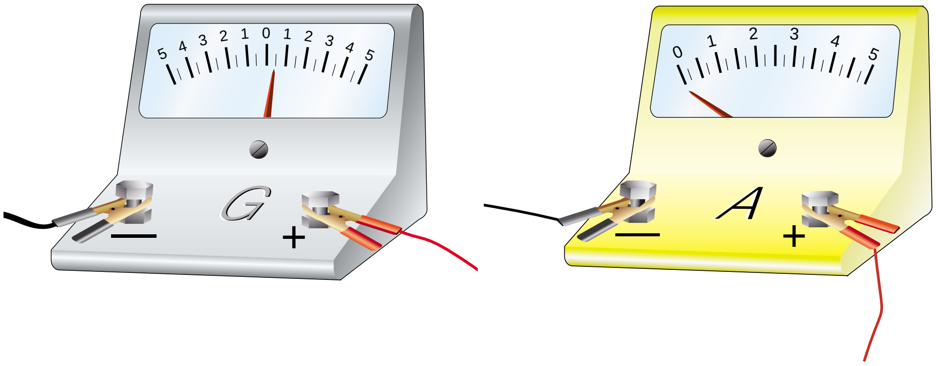


Figure 4.11 A galvanometer (left) and ammeter (right) both measure electric current.

Pause& Reflect

Start a table in your Science Log for symbols and units, like the one shown in Table 4.2. Each time you encounter a new unit, add it to your table.

DidYouKnow?

The galvanometer is named after Luigi Galvani (1737–1798), an Italian scientist who first recorded the presence of electric current. A galvanometer can accurately measure both the direction and strength of an electric current. The first galvanometers were based on a discovery made by Hans Oersted in 1819. He observed that a magnetic compass needle rotated slightly when electric current flowed in a nearby wire.

Skill FOCUS

For more information about using ammeters and voltmeters, turn to Skill Focus 14.

Measuring Voltage

Energy for pushing electrons is available if positive and negative charges are separated. A battery, for example, forces electrons to accumulate at one terminal (connection), making it negatively charged. At the same time, electrons withdraw from the other terminal, leaving it positively charged. In a battery, energy from chemical reactions does the work of separating the charges (see Figure 4.12). The energized electrons now have the ability to do work on something else, such as lighting a bulb or heating a burner on a stove.

All forms of energy are measured in joules (J). However, when describing the energy of electrons in an electric circuit, we describe the energy possessed by a standard unit of charge instead of the total energy of all of the charges. As well, we always compare one point in a circuit to another. The term **potential difference** means the difference in energy per unit of charge between one point in the circuit and another point in the circuit. Potential difference is commonly referred to as **voltage**.

The standard unit for potential difference is the **volt** (V), named after Alessandro Volta (1745-1827), who built the first battery. Most electrical devices require potential differences of 1 to 120 V, but higher voltages are not uncommon (see Table 4.5). Voltage is measured with a **voltmeter**, such as the one shown in Figure 4.13. In circuit diagrams, the symbol for a voltmeter is a circle with "V" at the centre.

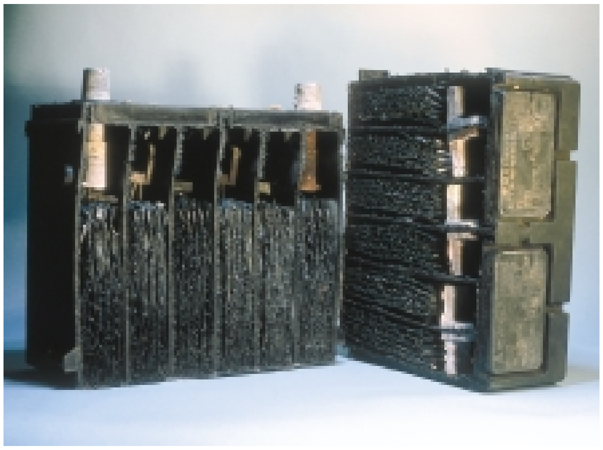


Figure 4.12 Chemical reactions inside the six cells of this car battery separate electrical charges, increasing their energy.

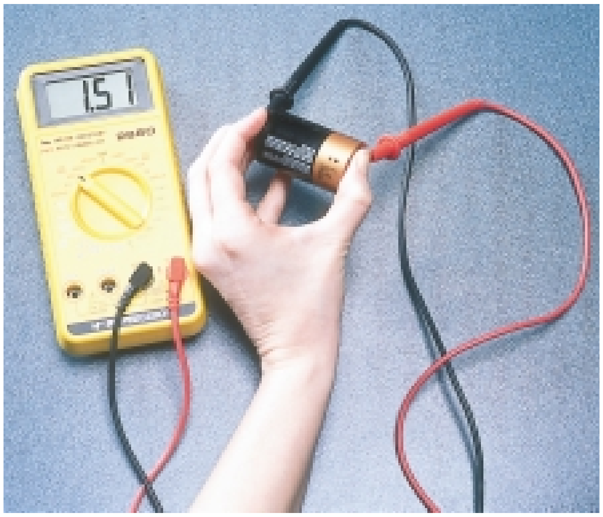


Figure 4.13 This digital multimeter can measure voltage, current, and other characteristics of electric circuits.

Table 4.4 Symbols and Units for Potential Difference

Quantity	Symbol	Unit
potential difference (voltage)	V	volt (V)
energy	E	joule (J)

Table 4.5 Voltage in Household Appliances

Energy Source	Voltage (V)
"AA"cell	1.5
household wall plug	120
electric stove wiring	240
television high-voltage supply	200 000

Pause& Reflect

Add the symbols and units for energy and potential difference (voltage) to the table in your Science Log.

INQUIRY

INVESTIGATION 4-A

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Current and Voltage

In this investigation you will construct a simple circuit and then use an ammeter and voltmeter to find out how the electric current and voltage (potential difference) vary at or across different points within the circuit.

Apparatus

ammeter
voltmeter
knife switch
2 D-cells in battery holder
2.5 V bulbs (2) in sockets
3.7 V bulb (1)
4 copper wires with alligator clips

Safety Precautions

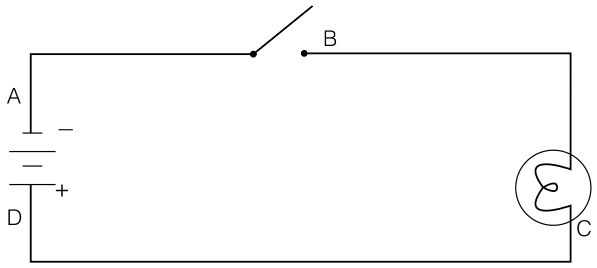
Part A: Measuring Current

Question

Does the electric current flowing through a circuit vary at different points within the circuit?

Prediction

Examine the diagram below and predict whether the electric current at points B, C, and D will be higher, lower, or equal to the current at point A.



Procedure

① Using the 3.7 V bulb, construct the circuit illustrated.

② Plan how to place your ammeter into the circuit. You must force all the current to flow through the ammeter to get to the rest of the circuit. The positive terminal of the ammeter must lead to the positive end of the battery.

③ Measure the current at point A with the switch open, and again with the switch closed. **Record** the ammeter readings in a copy of the current observations table.

④ Repeat step 3 at the points labeled **B**, **C**, and **D** on the circuit diagram.

Current Observations

Ammeter location	Electric current (mA)	
	Switch open	Switch closed
A		
B		
C		
D		

Analyze

1. Compare the electric current flowing out of the battery and into the battery (points A and D). Suggest an explanation for your observation.

2. Compare the current on either side of the bulb (points B and C).

3. What effect did opening and closing the switch have on the current?

Conclude and Apply

4. For an electric current to flow in a circuit, what conditions must exist?

5. Hypothesize about factors that affect the strength of an electric current in a circuit. If time permits (and with your teacher's permission), test your hypothesis.

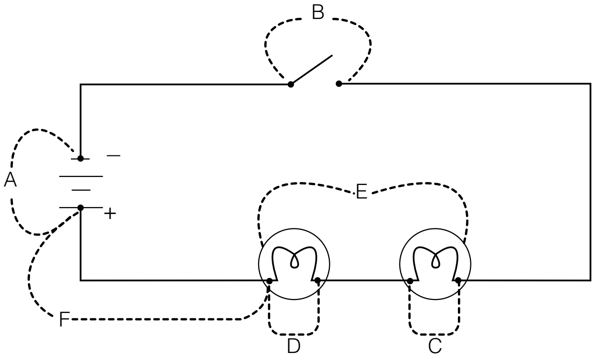
Part B: Measuring Voltage

Question

How does the voltage (potential difference) across different components within a circuit compare?

Prediction

Examine the diagram below and predict whether the potential difference (voltage) across points **B**, **C**, **D**, **E** and **F** will be higher, lower, or the same as the voltage across point **A**.



Procedure

① Using the 2.5 V bulbs, construct the circuit illustrated.

② Use the diagram to plan how to connect your voltmeter to the circuit. One lead from the voltmeter must be connected to each side of a circuit component. The positive terminal of the voltmeter must lead to the positive end of the battery.

③ Measure the potential difference (voltage) across point A when the switch is closed, and **record** the voltmeter reading in a copy of the voltage observations table.

④ Repeat steps 2 and 3 at the points labeled **B** , **C**, **D**, **E** and **F** on the circuit diagram.

⑤ Replace the 2.5 V bulb at point D with a 3.7 V bulb and measure the voltage at point D. Compare the brightness of the 3.7 V bulb with the original 2.5 V bulb.

⑥ Remove both bulbs and measure the voltage at point E.

Voltage Observations

Location of Voltmeter	Voltage(V)
A	
B	
C	
D	
E	
F	
D (with 3.7 V bulb)	
E (bulbs unscrewed)	

Analyze

1. Which parts of your circuit
   (a) provide electrical energy
   (b) use electrical energy?

2. Compare the potential difference (voltage) across the battery (A) to the voltage across the load (E).

3. How does the energy provided to the circuit compare to the energy used?

4. How does the potential difference across an individual bulb (C or D) compare to the voltage across the entire load (E)?

Conclude and Apply

5. How did the brightness of the 2.5 and 3.7 volt bulbs compare? Use your voltmeter readings to suggest an explanation for this difference.

6. How did the potential difference across point E change when the bulbs were removed? Suggest why.

Rivers of Electricity

Electric circuits are often compared to water systems. Electric charge flows through the parts of the circuit, just as water flows through pipes or along a river channel. The energy of the moving charge is changed to different forms as current passes through the load, just as the energy of moving water can be harnessed as it flows downhill. Study Figure 4.14 and identify the following points in each diagram:

(a) highest energy
(b) lowest energy
(c) control
(d) load

DidYouKnow?

An arrow labelled with the symbol *e*⁻ is often used to indicate the direction of electrical charge movement in a circuit. In solid conductors, the moving charges are electrons.

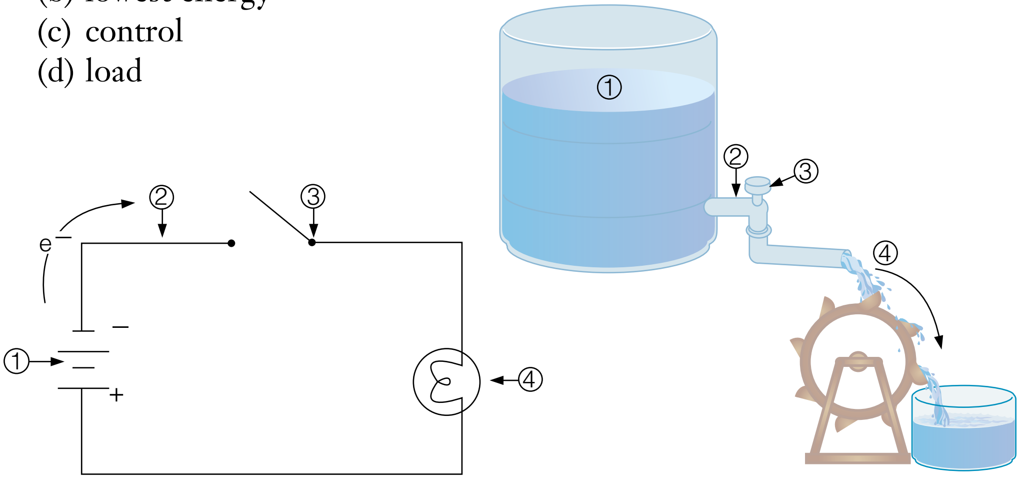


Figure 4.14 An electric circuit is similar in many ways to a water system.

TOPIC 2 Review

1. Copy the electric terms listed below into your notebook. Write the water (hydraulic) related term from the column of terms on the right that best typifies each electric term next to it. For each pair of terms, describe why you think they are similar.

(a) load	**(1)** pump
(b) switch	**(2)** pressure
(c) electric current	**(3)** pipe
(d) voltage	**(4)** water wheel
(e) battery	**(5)** valve
(f) conductor (wire)	**(6)** flow rate

2. Draw a circuit diagram using symbols. Include a battery, a switch, a lamp, an ammeter, and conducting wires. Add arrows to show the direction of the flow of electrons. Describe the function of each part of the circuit.

3. Explain how to connect a voltmeter to a circuit to measure the voltage across a light bulb. Use a sketch to clarify your explanation.

4. **Apply** Predict which current will be greater, the current passing through an electric iron or the current passing through an electric razor, when each is plugged into a 120 V outlet. Explain how you made your prediction.

5. **Thinking Critically** If a circuit contains a 12 V battery, a switch, and a light bulb, what is the voltage across the light bulb?

TOPIC 3 Resisting the Movement of Charge

Resistance is a property of a substance that hinders motion of electric charge and converts electric energy into other forms of energy. For example, the resistance of the tungsten wire filament in a light bulb is more than 400 times greater than the resistance of a similar copper wire. When current flows through the high-resistance filament of the light bulb, the filament converts much of the energy of the current into light and heat. If the same current flows through a copper wire, the amount of energy converted into heat is so small that you hardly notice it.

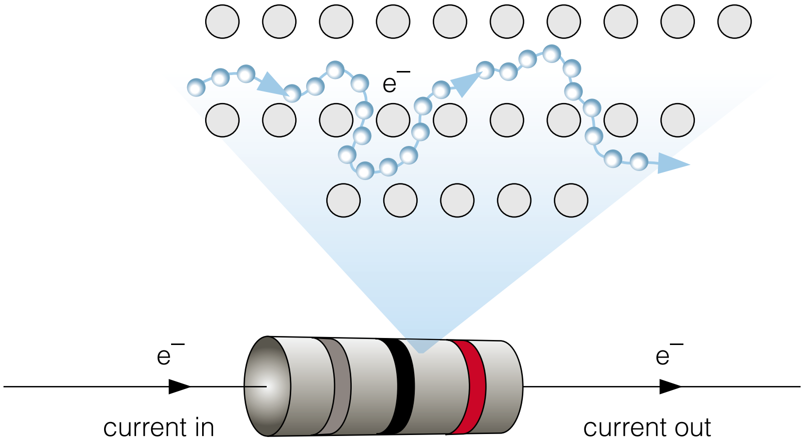


Figure 4.15 Negatively charged electrons must force their way through solids, overcoming resistance caused by the attraction of positively charged atomic nuclei and the repulsion of other electrons.

Within an electric circuit voltage, current, and resistance are closely related. If current is described as the movement of electrons through conductors, and voltage is what makes the electrons move, then resistance is what opposes the motion of the electrons.

The language of resistance can be tricky. A good conductor, like copper, allows electric charge to move easily through it. That is, a good conductor has *low* resistance. Poor conductors, on the other hand, oppose the movement of charge. In other words, poor conductors have *high* resistance. Just as in a game of golf or hearts, where the best players have the lowest scores, better conductors have lower resistance.

DidYouKnow?

Georg Ohm was the first person to publish results of experiments on the resistance of wires of various sizes. Ohm applied a voltage across wires of many different lengths and diameters, and measured the current through them. He discovered that, for each wire, the ratio of voltage to current stayed the same. Today, we would say that the *resistance* of the wires was constant. We would describe the wires as *ohmic resistors*.

Find Out ACTIVITY

Resistance Roadblock

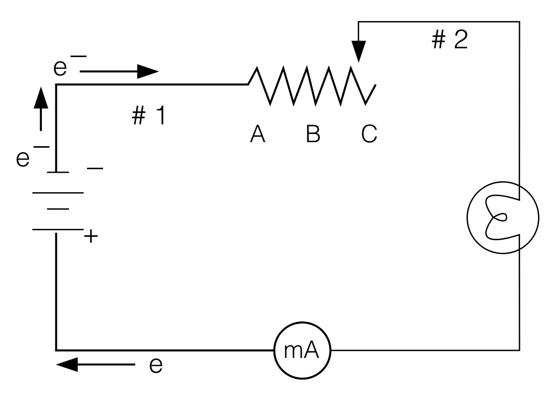
Some electronic components are made of materials that are poor conductors. Why would high resistance be useful in a circuit? How does increasing or decreasing the resistance within a circuit affect the energy of electrons moving in the circuit?

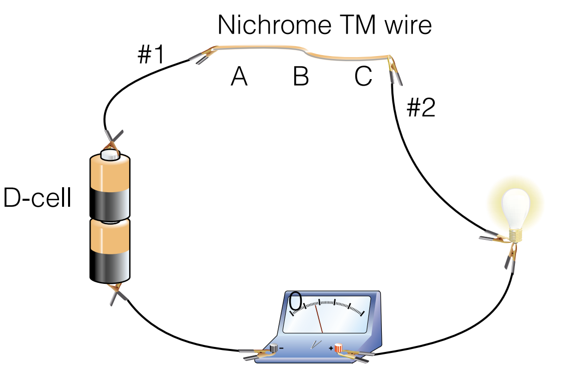
Safety Precautions

Handle the Nichrome™ wire carefully while it is connected to your circuit. It may heat up enough to cause minor burns.

Materials

1 m Nichrome™ wire
2.5 V bulb and holder
2 D-cells in holders
milliammeter
3 copper wires with alligator clips





Procedure ✷ Performing and Recording

1. Copy the table below into your notebook.
2. Complete the prediction portion of the table for different positions of lead #2 (clipped to the Nichrome™ wire).
3. Construct the circuit shown in the diagram.
4. Slide lead #2 to positions A, B, and C and record your observations of the brightness of the bulb and the reading from the ammeter.

Current & Bulb Brightness

Location of lead #2 on Nichrome™	Current (mA)		Bulb brightness	
	Predicted (low, medium, high)	Actual	Predicted (dim, medium, bright)	Actual
A				
B				
C				

What Did You Find Out? ✷ Analyzing and Interpreting

1. How did the amount of current change when you moved the clip and increased the length of Nichrome™ wire in the circuit?
2. In general, suggest how the amount of resistance in the circuit affects the electric current flowing through the circuit.
3. What does the brightness of the bulb tell you about energy of the electrons passing through it?

Extension

1. Into what form was electrical energy converted by the Nichrome™ wire? Give evidence to support your answer.
2. What items in your home offer resistance to the flow of electrons? How do you know?

The standard unit for resistance is the **ohm**, symbolized by the Greek letter omega (Ω). Electronic devices contain resistors with a huge range of values, from a few thousandths of an ohm (milliohms) to many millions of ohms (megohms). Resistance can be measured directly with an **ohmmeter**, but in practice, technicians are more likely to use a multi-purpose electronic measuring instrument (a "multimeter") set to measure resistance.

DidYouKnow?

A 100 watt light bulb has resistance of about 144 Ω when connected to a 120 V supply. Typical stereo speakers act as though they have a resistance of 2 Ω to 8 Ω to the current flowing through them. Many headphones and earbuds have resistance of 32 Ω. Dry human skin has resistance of about 500 000 Ω (500 kΩ or 0.5 MΩ).

Calculating Resistance

As you saw in the previous activity, resistance affects the current flowing in a circuit. Resistance also affects the potential differences between different points in complex circuits with several loads. Georg Ohm found that it is possible to calculate the resistance of a circuit, or part of a circuit, from measurements of current and voltage. Can you see how this can be done from the measurements in Table 4.6?

Table 4.6 Resistance, voltage, and current in a simple circuit

Resistance (Ω)	Voltage (V)	Current (A)
1	1	1
1	10	10
2	10	5
5	10	2

Pause& Reflect

Add the symbol for resistance *(R)* and the unit ohm (Ω) to your table of symbols and units in your Science Log.

Electrical resistance is calculated by finding the ratio of the voltage across the load (V) to the current through the load (I). Using R to represent resistance, the mathematical equation for resistance is

$$R = \frac{V}{I} \qquad \textbf{resistance} = \frac{\textbf{voltage (potential difference)}}{\textbf{current}}$$

According to this relationship, the units of resistance are volts per ampere *(V/A)*, which are equivalent to ohms. The expression above is called **Ohm's law**. Since Ohm's law can be solved for any of its variables, you will also see it expressed in these forms.

$$\text{voltage (potential difference)} = \text{current} \times \text{resistance} \quad V = IR$$

$$\text{current} = \frac{\text{voltage (potential difference)}}{\text{resistance}} \quad I = \frac{V}{R}$$

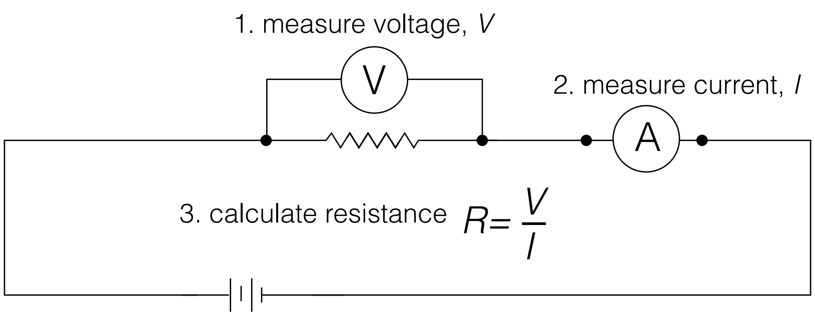
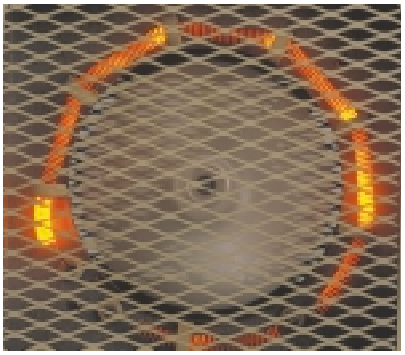


Figure 4.16 Ohm's law allows you to calculate resistance from current and voltage measurements.

Model Problem



What is the resistance of an electric heater, if a current of 12.5 A runs through it when it is connected to a 120V wall outlet?

Given

$I = 12.5$ A
V = 120V

Required

Resistance, R, in ohms (Ω)

Analysis

Use the expression $R = \frac{V}{I}$ to find resistance.

Solution

$$\begin{aligned} R &= \frac{V}{I} \\ &= \frac{120\text{ V}}{12.5\text{ A}} \\ &= 9.60\ \Omega \end{aligned}$$

Paraphrase

The resistance of an electric heater is 9.60 Ω, if the current through it is 12.5 A, with a 120 V supply.

Practice Problems

Use an appropriate form of Ohm's law to solve each problem. Show your work for all questions.

1. What is the resistance of a light bulb if a 12 V battery sends a current of 2.4 A through it?
2. A toaster with a resistance of 145 Ω is connected to a 120 V source. What current will flow through the toaster?
3. What is the potential difference across a 1 500 Ω resistor carrying a current of 0.075 A (75 mA)?
4. **Apply** An extension cord rated at 15 A is connected to a 120 V supply. What is the *smallest* resistance with which the cord can safely be used?

Resistors

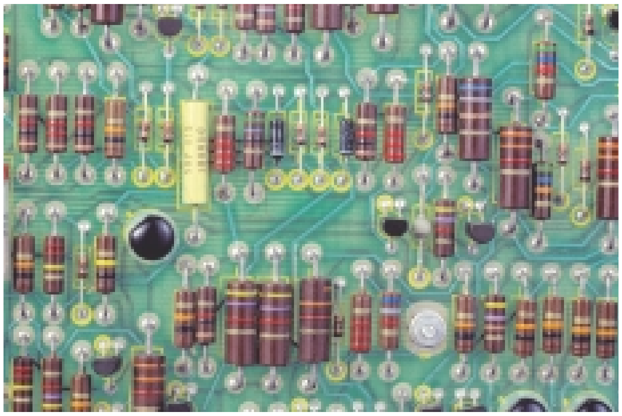


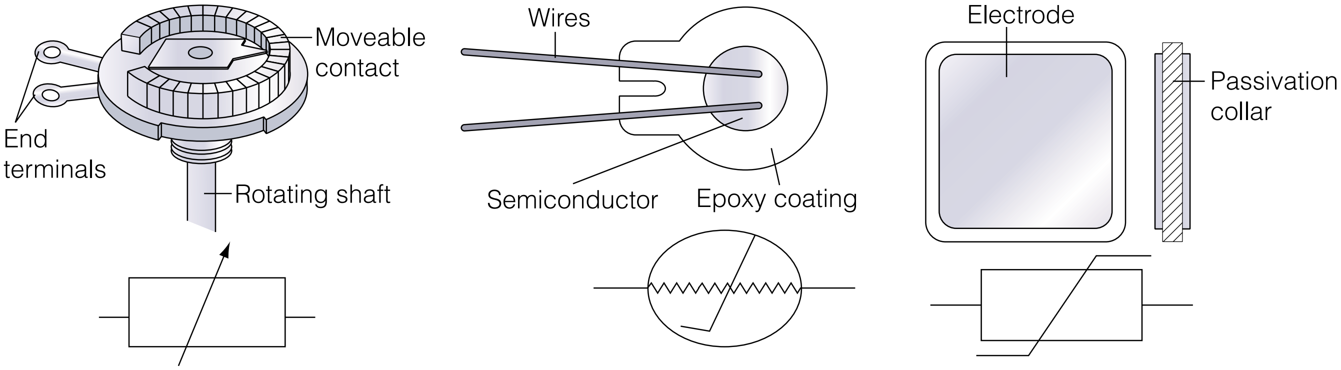
Figure 4.17 The coloured stripes on these resistors show their resistance and quality in coded form.

In electronic circuits, resistance is useful for more than changing the energy of moving charges into heat. One very common type of electronic component — the resistor — is used to control current or voltage to suit the specific needs of other electric devices in the circuit. Circuit resistors are usually made of a heat-conducting ceramic core coated with materials such as carbon, metal oxides, metal film, or resistance wire. Modern "chip" resistors are made of similar materials, but they are very small. Instead of being soldered into holes in a circuit board, as in Figure 4.17, they are mounted directly on the surface of the board.

Variable Resistors

Variable resistors do not have a fixed resistance. Instead, their resistance changes in response to temperature, light, voltage, or some other variable. The Nichrome™ wire that you have used in several activities acted as a variable resistor. When you changed the length of wire, you also varied the resistance in the circuit. Variable resistors are used in a wide variety of electronic devices, from simple light dimmers and motor speed controls to surge protectors and refrigerator and stove temperature controls.

Figure 4.18 Common types of variable resistors



(a) Rheostats have a slide-shaped armature that controls the total resistance. They are usually found in high-current electric circuits, such as power-distribution equipment.

(b) A thermistor is sensitive to changes in temperature. Thermistors are used in thermostats and heat sinks.

(c) Varistors are voltage-dependent resistors used in a circuit to protect it from high-voltage surges.

INQUIRY

INVESTIGATION 4–B

SKILLCHECK

Initiating and Planning
- ✸ Performing and Recording
- ✸ Analyzing and Interpreting
- ✸ Communication and Teamwork

Voltage, Current, and Resistance

Inside electronic devices such as CD players and radios you can find many small resistors. In this investigation you will examine the relationship between the electric current flowing through a resistor, the voltage across its ends, and the known resistance of the resistor.

Question

What is the relationship between resistance, the voltage across the ends of a radio resistor, and the electric current flowing through it?

Hypothesis

Use Ohm's law to suggest a general answer to the question.

Safety Precautions

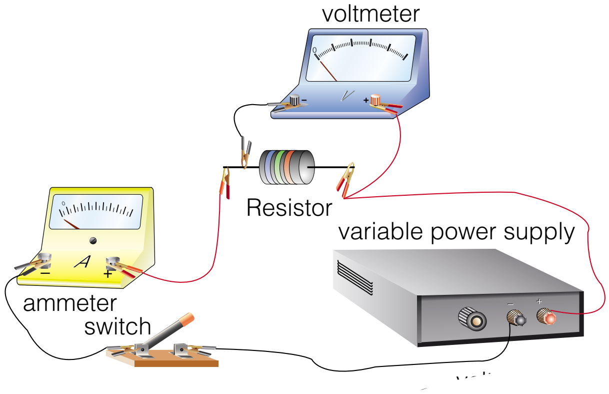
- Avoid touching resistors while current passes through them and immediately afterwards. They can get hot enough to burn you.
- Do not use the power supply to generate currents greater than 0.5A or voltages greater than 15V.

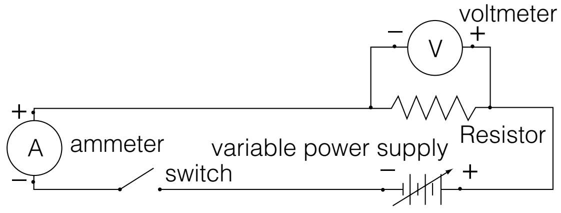
Apparatus

ammeter or milliammeter
voltmeter
variable low-voltage power supply or several batteries
6 copper wires with alligator clips
2 resistors (of different known resistance between 10 and 60 ohms)
switch

Procedure

1. Copy the table below into your notebook.
2. Construct a circuit similar to the one shown in the diagram.
3. Close the switch. Adjust the power supply until the voltmeter shows a convenient potential difference such as 1.0 V across the resistor. **Record** the exact voltage and the corresponding current reading on the ammeter.
4. Repeat step 3 an additional four times for voltages between 1.0 and 6.0 V.
5. Repeat steps 3 and 4 for a second resistor, using the same potential differences as previously.





Analyze

1. What happened to the amount of electric current as you increased the voltage?
2. For similar voltages, compare the amount of current passing through each of the resistors.

Conclude and Apply

3. Using Ohm's Law (*R* = *V*/*I*) calculate the resistance for each trial. Remember that if the potential difference (*V*) is in volts, current (*I*) must be expressed in amperes. If your current measurements are in milliamperes (mA), you can convert them to amperes by dividing by 1000.
4. For each resistor, how well do the five calculated values for resistance agree? Why are the calculated values not usually identical?
5. How well do the calculated resistance values compare to the value marked on each resistor? Suggest an explanation for any difference in the values.
6. How well do your results support Ohm's law? Give evidence to support your answer.

Extend Your Knowledge and Skill

7. Design an experiment to determine if a light bulb behaves according to Ohm's law. Obtain a light bulb from your teacher. Make the necessary measurement using a wide variety of voltages and currents.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Investigate a variety of resistor-related web sites where you can find out the latest in resistor design and innovations, as well as on-line guides to the resistor colour code. Use the code to find the rated resistance for some of the resistors you used in this Investigation. Visit the above web site. Go to the web site above, and click on Web Links to find out where to go next.

Electric Current, Voltage, and Resistance

Resistor # (Known resistance) (Ω)	Voltage (V) (V)	Measured Electric current (I) (mA)	Calculated Electric current (I) (A)	Calculated resistance (R) (Ω)
1 (known Ω)				
2 (known Ω)				

Types of Circuits

All the circuits you have constructed so far in this Unit have had a single source of current connected to a single load and, sometimes, a single control switch. In practice, electrical circuits are seldom that simple. Think of your home, for example. Lamps, televisions, stoves, refrigerators, computers, and many other devices operate from the same source of electric energy, yet each appliance seems to operate independently of the others. The circuits are constructed to allow each device to be turned on, while the others remain off. How is this done? You can find out by studying the two basic patterns for connecting several loads into a single circuit.

Series circuits have only one current path. All the moving charges travel through each component in the circuit. You can think of a series circuit as a set of parts connected end to end.

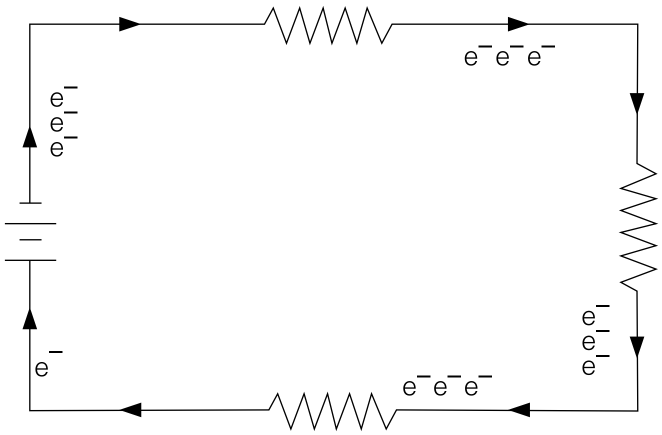


Figure 4.19 A series circuit has a single current path. These three loads are connected in series.

Parallel circuits have several current paths. The total current is divided, with some of the moving charges travelling through each **branch**, or part of the circuit. You can think of of a parallel circuit as a set of branches connected side by side.

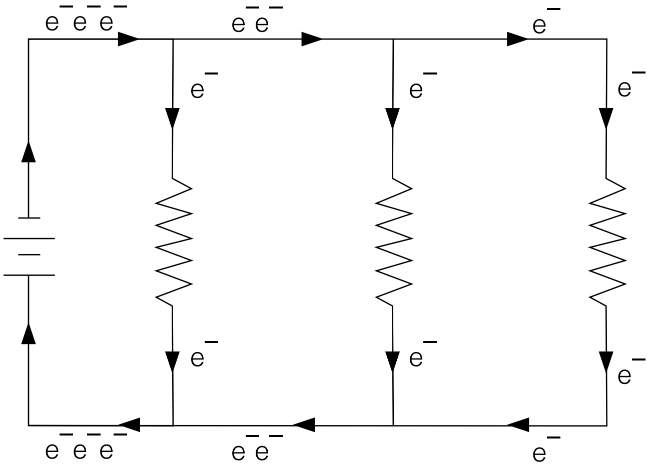


Figure 4.20 A parallel circuit has several current paths. These three loads are connected in parallel.

Each type of circuit—series and parallel—has specific characteristics that make it useful in certain situations. As well, circuits can be made with some parts connected in series, and others in parallel. Current sources, as well as loads, can be connected in series and in parallel. You may investigate these complex situations in future courses.

INQUIRY

INVESTIGATION 4-C

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Series and Parallel Circuits

Depending on the requirements of a circuit, it may be wired in series or in parallel. You will explore the advantages and disadvantages of each type of circuit in this investigation.

Question

How does adding extra bulbs affect the other bulbs in a series or parallel circuit?

Hypothesis

Write a hypothesis that answers the questions for each type of circuit. In your data tables, predict what will happen to the other bulbs as bulbs are added to either circuit. How will the addition of bulbs affect the amount of current flowing through the circuit?

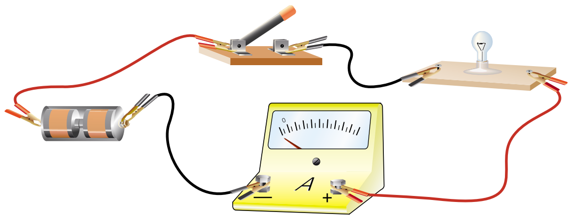
Safety Precaution

Apparatus

2 1.5 V D-cells and cell holders
3 3.7 V bulbs with holders
7 wires with alligator clips
1 ammeter
1 switch

Part A: Current and Brightness in a Series Circuit

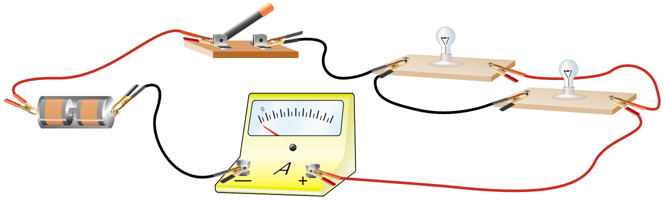
Series circuit layout	Predicted brightness	Observed brightness	Current (A)
1 bulb			
2 bulbs			
3 bulbs			
3 bulbs, 1 unscrewed			



Part A

Part B: Current and Brightness in a Parallel Circuit

Series circuit layout	Predicted brightness	Observed brightness	Current (A)
2 bulbs			
3 bulbs			
3 bulbs, 1 unscrewed			



Part B

CONTINUED ▶

Part A: Series

Procedure

① Copy the table on the previous page into your notebook.

② Set up your first series circuit (with one bulb) as shown in the diagram.

③ Close the switch and **record** your observations about the brightness of the bulb and the electric current flowing through the circuit.

④ Repeat steps 2 and 3 with two bulbs and then with three.

⑤ While all three bulbs are lit, unscrew one of the bulbs and **record** your observations in your table.

Analyze

1. How does the brightness of the bulbs change as more bulbs are added to the series circuit? How did the electric current as measured by the ammeter change?

Conclude and Apply

2. Using your results, explain why the brightness of the bulbs changes. Hint: use your knowledge of Ohm's Law and resistance to answer the question.
3. What happened to the series circuit when one of the bulbs was unscrewed? Using your knowledge of electric circuits, explain why this happened.

Extension

4. Predict what would happen if you continued to add more bulbs to the series circuit. Explain your answer.
5. Think of an example of a real-life circuit that behaves in the same way as the circuit you have just constructed.
6. Based on your observations, describe two advantages and two disadvantages to using this type of circuit.

Part B: Parallel

Procedure

① Copy the table on the previous page into your notebook.

② Set up your first parallel circuit (with two bulbs) as shown in the diagram.

③ Close the switch and **record** your observations about the brightness of the bulbs and the electric current flowing through the circuit.

④ Repeat steps 2 and 3 with three bulbs.

⑤ While all three bulbs are lit, unscrew one of the bulbs and **record** your observations in your table.

Analyze

1. How does the brightness of the bulbs change as more bulbs are added to the parallel circuit? How did the electric current as measured by the ammeter change?

Conclude and Apply

2. Using your results from the activity, explain any changes or lack of changes in the brightness of the bulbs.
3. What happened when one of the bulbs was unscrewed? Using your knowledge of electric circuits, explain why this happened.

Extension

4. Predict what would happen if you continued to add more bulbs to the parallel circuit. Explain your answer.
5. Think of and describe an example of a real-life circuit that behaves in the same way as the circuit you have just constructed.
6. Based on your observations describe two advantages and two disadvantages to using this type of circuit.

House Wiring

Practical electric circuits for the home are parallel circuits. The voltage across each load in a parallel circuit is the same. Turning on one appliance will not reduce the energy available to other loads. Plugging in an electric kettle, for example, will not cause lights on the same circuit to dim.

One potential problem does exist with parallel circuits. Current through wires connected to the source increases whenever another branch in the circuit is closed. When you turn on any appliance in your home, the current in the wires closest to the source increases. More current means the temperature of the conducting wires rises. If you turn on too many appliances at the same time and the current increases too much, the wires could become hot enough to start a fire. To guard against an electrical fire, household circuits always include fuses or circuit breakers (see Topic 7).

Pause& Reflect

Make a chart in your Science Log that summarizes the characteristics of series and parallel circuits. Make two columns, one with the heading "Series Circuits" and the other with the heading "Parallel Circuits." Under each heading, write a summary of the important facts about each type of circuit. Leave room for additional information.

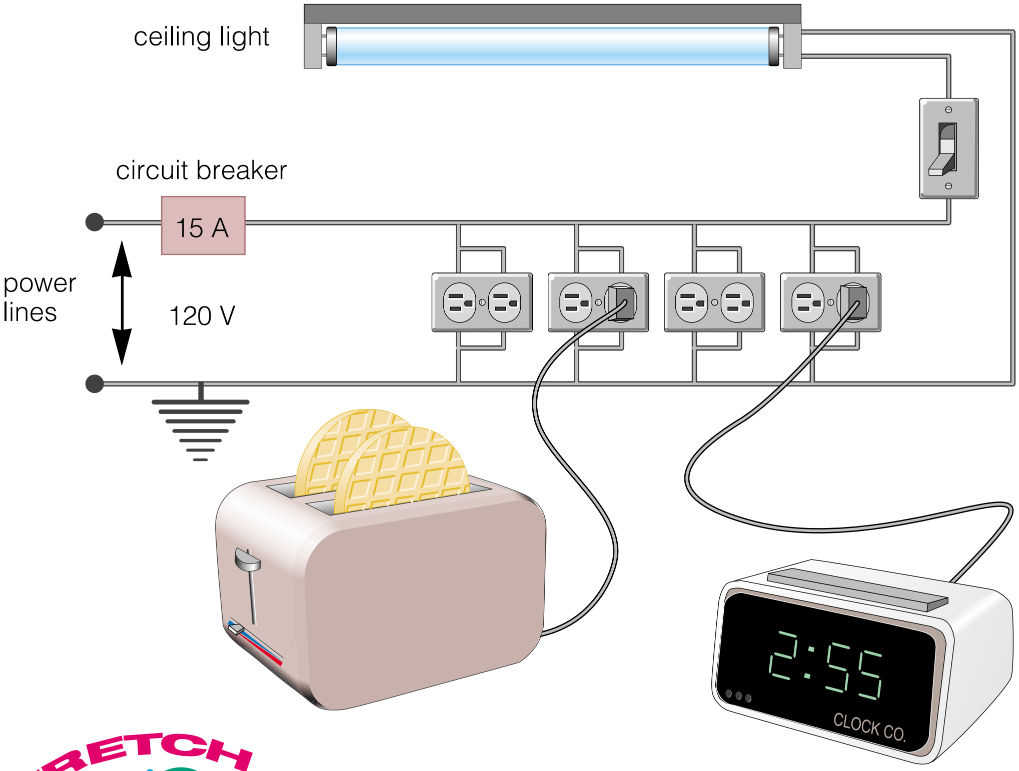


Figure 4.21 Household wiring connects appliances and lights in parallel along each branch circuit.

STRETCH Your Mind

In the series-wired circuits you have constructed in class, if one bulb burns out none of the others will light. In the early days of decorative lighting people had to remove and test each bulb in order to find the one that had burned out, a frustrating task indeed. Modern strings of lights are wired so that if one bulb burns out, the others keep operating. There are two common ways in which this problem has been solved. Can you describe both possible solutions?

PROBLEM-SOLVING

INVESTIGATION 4-D

Is Resistance Futile?

Can you design a simple electric circuit which allows you to dim a light or to turn off one light while leaving others operating? In this investigation you will use your knowledge of circuits and resistors to control electric current in specific, useful ways.

Challenge

Design and construct five separate circuits, each having *one* of the following characteristics.

(a) one bulb can be turned off while the other stays lit
(b) both bulbs can be turned off at the same time
(c) maximum current flows
(d) minimum current flows
(e) one light can be dimmed without affecting the brightness of the other light

Each circuit must use two light bulbs and any other necessary apparatus from the list below.

Apparatus

2 3.7 V bulbs
milliammeter
2 D-cells and holders
1 knife or button switch
2 bulb receptacles
1 m of Nichrome™ wire
1 m of copper wire
1 paper toilet paper roll
1 lead pencil
3 resistors (of various resistance)
6–8 wires with alligator clips

Safety Precautions

Design Specifications

A. Only the materials supplied by the teacher can be used to construct your circuit. You are not required to use *all* materials.

B. Each circuit must meet one of the design challenges.

C. Circuit components may not be added or removed during the operation of your circuit.

Plan and Construct

① With your group, brainstorm possible designs for each of the five required circuits. Choose one design for each circuit to construct and test.

② Use correct symbols to draw your five proposed circuit designs. Indicate which challenge each circuit is designed to meet.

③ After receiving teacher approval, construct and test each circuit in turn. Adjust your design until each circuit meets its challenge and also satisfies the general design specifications.

Evaluate

1. Demonstrate the operation of each circuit as directed by your teacher. Describe which types of circuits you constructed (series, parallel,or a combination) and explain why your designs enabled (or did not enable) your circuit to meet its challange.

2. Prepare a revised diagram of any circuit which was changed from its original design. Explain the specific problem which the changes overcame.

3. Label each circuit diagram to show whether the lights were connected in series or in parallel.

4. What energy transformation occurred when current passed through each component listed?

(a) the Nichrome™ wire
(b) the light bulbs
(c) the resistors

5. Describe at least three practical applications for a circuit that has variable resistance.

6. When the bulb in your circuit is being dimmed, where does the "lost" energy go? Could this cause any problems for the designers of variable resistors? Explain your answer.

Even good conductors like copper wires oppose the flow of electric charge. Table 4.7 shows how the actual resistance of a wire depends upon physical properties such as its cross sectional area ("thickness"), which is commonly described by an American Wire Gauge (AWG) number. Thicker wires (larger cross-sectional area) have *lower* resistance for a given length. For example, heavy-duty appliance wiring (#12 AWG) has a relatively large diameter, giving it lower resistance and the ability to carry higher currents without overheating than thinner light-duty extension cords (#16 AWG).

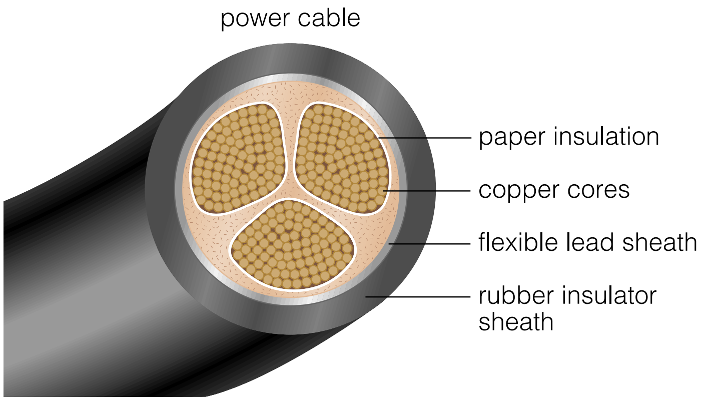


Figure 4.22 Power cables are made of many thin copper strands, which act together like one large-diameter conductor. This reduces resistance and heating and makes the cable more flexible.

Table 4.7 Factors Affecting Resistance of Wire

Factor	Effect
Length	Resistance *increases* with length. If the length doubles, the resistance doubles.
Cross-sectional Area	Resistance *decreases* with area. If the cross-sectional area doubles, the resistance is half as great.
Temperature	As the temperature of the wire increases, the resistance *increases*.
Material	Due to the structure of their atoms, some metals allow electrons to move more freely than others.

TOPIC 3 Review

1. In your own words, explain the meaning of electrical resistance.
2. What combination of units is equivalent to the ohm?
3. State Ohm's Law, and give the standard units for each quantity in it.
4. Explain the differences between a series circuit and a parallel circuit.
5. List three characteristics of a wire that affect its electrical resistance.
6. Which type of circuit, series or parallel, will produce the highest current through three bulbs? Give a reason for your answer.
7. **Apply** What is the voltage across an electric water heater element that has a resistance of 32Ω when the current through it is 6.8 A?
8. **Thinking Critically** Matt says that if the resistance to a load becomes larger, the current through it becomes larger as well. Angela says that if the resistance of a load becomes larger, the current will decrease. Do you agree with Matt or Angela? Explain your answer.

Wrap-up TOPICS 1-3

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

electric circuit
charged
neutral
electric current
static electricity
unbalanced charges
Laws of Charges
insulators
conductors
semiconductors
superconductors
electrostatic discharge
grounding
battery
switch
resistor
loads
voltage
amperes
galvonometer
ammeter
potential difference
resistance
ohm
Ohm's Law
series circuit
parallel circuit

Reviewing Key Terms

Copy and complete the statements below in your notebook.

1. The behaviour between charged and uncharged particles is explained by the ________________. (1)

2. The term that most accurately describes the electric condition that occurs when two different materials are rubbed together is ________________. (1)

3. A ________________ is a material with higher conductivity than insulators but lower conductivity than metals. (1)

4. Components within an electric circuit that convert electricity to other forms of energy are called ________________. (2)

5. Electric pressure or difference in electric potential is called ________________. (3)

6. The property of substance that hinders the motion of electric charges and converts electric energy into other forms of energy is ________________. (3)

7. A circuit with only one path along which a current can flow is a ________________. (3)

8. The relationship between voltage and electric current can be explained by ________________. (3)

Understanding Key Concepts

9. Explain how electric charges are produced. (1)

10. Can electric charges travel only through wires? Explain your answer and give at least two supporting examples. (1)

11. Describe the kinds of observations that led to the formation of the Laws of Charges. (1)

12. Describe how a buildup of electric charges can be neutralized. Provide at least two examples. (1)

13. What conditions must exist in order for an electric current to flow? (2)

14. Sketch how to connect (a) a voltmeter, and (b) an ammeter into a circuit. (2)

15. Write Ohm's law in the form used to find (a) resistance, (b) current, and (c) potential difference. (3)

16. Sketch circuit diagrams which show three load resistors connected (a) in series, and (b) in parallel. List important facts about current and potential differences in each circuit below the diagram. (3)

17. Describe at least three ways in which the resistance within an electric circuit could be reduced. (3)

TOPIC 4

The Energy Connection

What does the word "energy" mean to you? One definition of energy is "the ability to do work." Does that definition seem to apply to electricity? Electric motors certainly use electric energy to do work on objects by moving them. Energy, however, has another important characteristic: it appears in many forms. Some electrical devices, such as light bulbs and stoves, are designed to change electric energy into other forms of energy, such as light and heat. Other technology is able to transform heat, light and energy of movement (kinetic energy) into electrical energy. In this Topic, you will investigate a variety of forms of energy, and discover how they can be converted directly into electricity, and how electricity can be converted directly into other forms of energy.

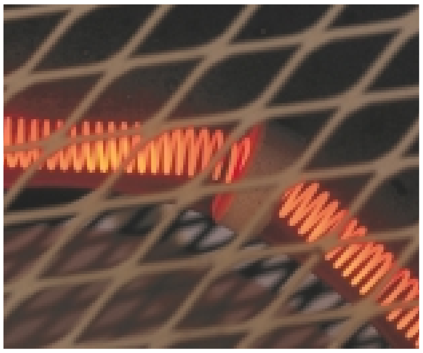


Figure 4.23 Heating elements convert electric energy into thermal energy. What other devices can you name that perform a similar energy conversion?

Find Out ACTIVITY

Something to Electricity: Electricity to Something

In your day-to-day life you encounter many devices that do useful tasks by converting electrical energy into some other form of energy. There are also many types of equipment that convert another form of energy into electricity.

Materials

reference materials (books, Internet, periodicals)
paper
pencil

Procedure

Analyzing and Interpreting

1. Copy the table at right into your notebook.
2. Think of familiar devices that convert electrical energy into some other form. Choose examples that cover a variety of forms of energy, and use them to fill in the table.
3. Choose one type of energy conversion and find out more about how it is achieved. Then choose a device that is designed to accomplish this conversion, and prepare a detailed explanation of how it works. Use a format specified by your teacher.
4. Present your findings about an energy-conversion device to the rest of the class. Discuss similarities and differences among the various conversion devices.

Device	Energy Conversion	
	Starting form	Final form
	electricity	
	electricity	
		electricity
		electricity

What Did You Find Out?

1. How does your list compare with that of your classmates? Add several more examples from their lists to your list.
2. Which type(s) of energy conversion occur most frequently in your list? Suggest a reason why this is so.

Word CONNECT

The movement of molecules within a substance produces thermal energy. *Heat* is defined as thermal energy that is transferred from a warmer substance to a cooler one.

Electricity and Heat

In appliances such as a stove or hair drier, electric energy is converted to heat as moving charges meet the resistance of a metal conductor. You observed this process in Find Out Activity: Resistance Roadblock in Topic 3. The opposite process is also possible.

Heat can be converted directly to electric energy using a **thermocouple**. A thermocouple is a loop of two wires made of different types of metals. The wires are wrapped together at both ends, or "junctions." When one junction is heated, a small electric current is produced. If the temperature difference between the junctions is increased, the current increases. For example, one junction might be cooled while the other is heated. If the positions of the hot and cold junctions are reversed, current will flow in the opposite direction.

The basic principle of the thermocouple was discovered by Thomas Johann Seebeck in 1821, and was named the Seebeck Effect. Seebeck originally concluded that any two metals could be used. However, it is now known that not every combination of metals works in thermocouples. Copper and constantan (a copper nickel alloy), or iron and constantan, are the most common metals used in modern industrial thermocouples.

Individual thermocouples produce only a small amount of current. They are widely used to obtain accurate temperature measurements where regular liquid thermometers cannot be used.

DidYouKnow?

If you hook the two wires leading from a thermocouple to a battery, one junction will get hot and the other will get cold.

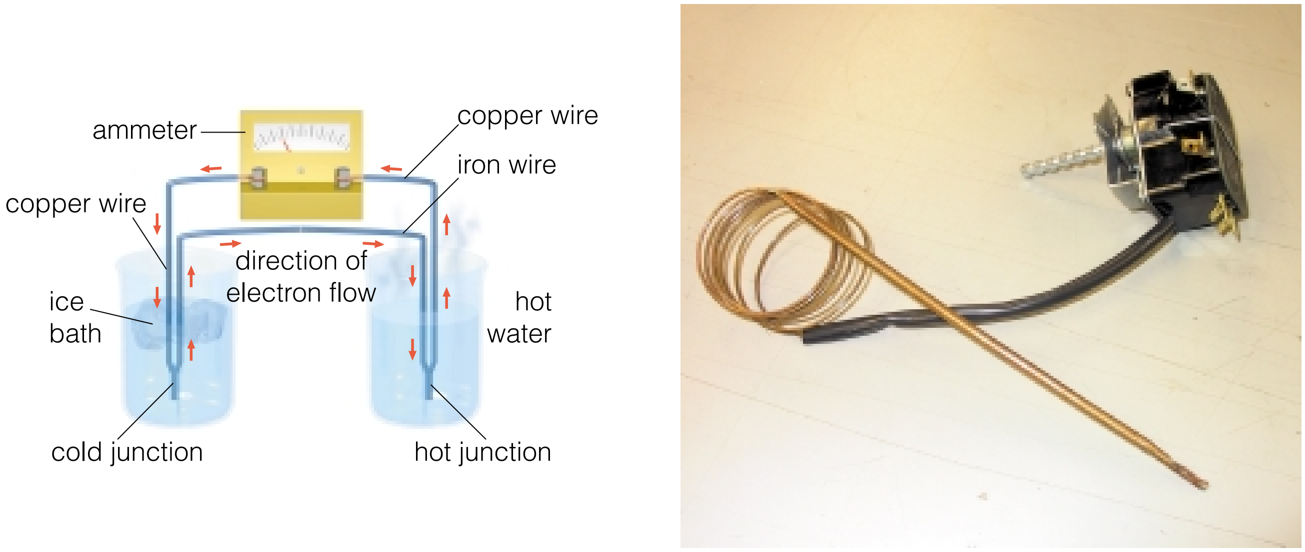


Figure 4.24 Thermocouples are rugged and can measure high temperatures. They are used as sensors in safety and control devices for furnaces, hot water heaters, and electric ovens.

A **thermo-electric generator** is a device based on a thermocouple that converts heat directly into electricity without moving parts. Heat from a gas burner or another heat source moves through several thermocouples connected in series — a *thermopile* — creating a potential difference. Thermopiles are extremely reliable, low-maintenance devices. They are used in remote locations to generate limited quantities of electrical energy that are sufficient to power, for example, emergency communications equipment.

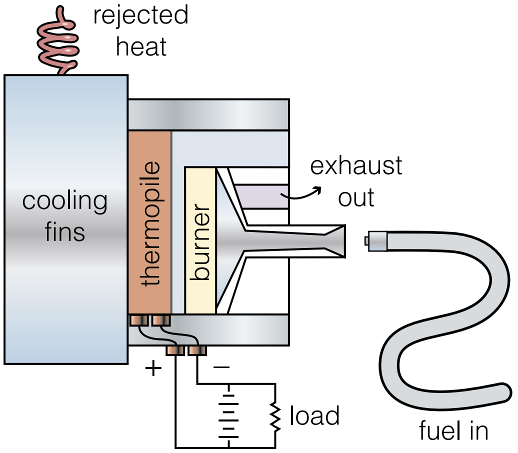


Figure 4.25 Thermo-electric generators such as this are manufactured by Global Thermoelectric, an industry-leading company based in Calgary.

On one side of the thermopile, a gas burner or other heat source is installed. The opposite side is kept cool by components such as aluminum cooling fins or heat pipe assemblies. Operating generators generally maintain temperatures of approximately 540°C on the hot side and 140°C on the cold side. The heat flow through the thermopile creates a steady flow of electricity. Individual thermo-electric generators can range in output size from 15–550 W and can be combined to produce up to 5000 W.

Electricity to Motion

How can sound be produced by tiny electric watches or the paper-thin sound modules in "talking" greeting cards? There is no room in these devices for even the smallest loudspeaker. Instead, sound is produced when an electric current causes vibrations in a tiny crystal — the piezoelectric effect. *Piezo* in Greek means pressure or push. When a piezoelectric crystal such as quartz or Rochelle salt is connected to a potential difference, the crystal expands or contracts slightly. Any material touching the crystal experiences pressure, which can create sound waves or vibrations. This link between electricity and pressure was first investigated in 1880 by two young French scientists, Pierre and Jacques Curie, who were 21 and 24 at the time.

Modern researchers have developed non-crystalline materials that move in response to an electric current. Such materials have many potential uses. For example, using a flexible polymer (plastic) with this property, Joseph Bar-Cohen, an American physicist, has created a robotic hand with four "fingers." When a voltage is applied, the plastic "fingers" bend, gripping any small object between them. Bar-Cohen's experimental device can lift only 10 g, the mass of a small ball point pen, but it is inexpensive, durable, and light.

Cool Tools

A scanning tunnelling microscope (STM) is one of the few machines capable of producing images of individual atoms. Parts of an STM must make incredibly small movements of only a few nanometres (10^{-9} m). The motion is produced by piezoelectric ceramic wafers, which move very slightly when a low voltage is applied to them.

Motion to Electricity

A barbecue "spark" lighter uses the piezoelectric effect in reverse. While a piezoelectric crystal is being compressed or pulled, a potential difference builds up on opposite sides of the crystal. Conductors attached to the crystal can connect it to a circuit, where the crystal acts as a source of electric energy. In a barbecue lighter, this creates a spark. Devices such as crystal microphones and some types of pressure sensors use the changing voltage from a piezoelectric crystal to control much larger electric currents in amplifiers and recording equipment.

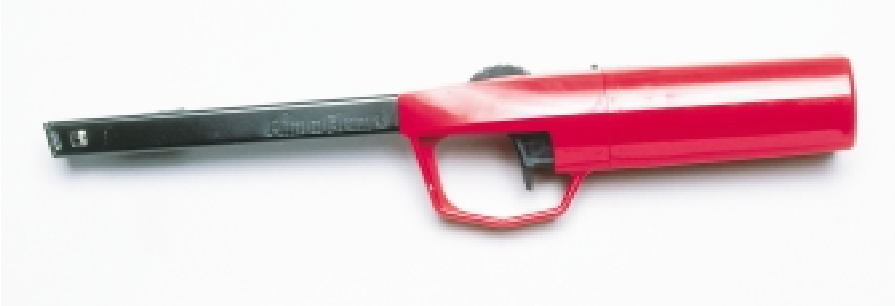
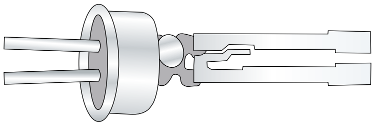


Figure 4.26 Squeezing the handle of a barbecue spark lighter slams a tiny hammer against a piezoelectric crystal, generating a potential difference of thousands of volts and a miniature lightning bolt across the spark gap.

DidYouKnow?

In 1927, Warren Morrison, a Canadian engineer working for Bell Laboratories in the United States, invented the quartz clock and revolutionized the way time was kept. The most common crystals are quartz crystals. Quartz is a piezoelectric material, and quartz crystals vibrate when a voltage from a battery is applied to them. Quartz watch crystals act as miniature tuning forks that vibrate 32 768 times per second. Other types of crystals vibrate at more than 50 million times per second.



Find Out ACTIVITY

Flashing Rocks

The piezoelectric effect produced by certain types of crystals can be observed as flashes of light as two crystals (rocks) are hit together. This activity allows you to experience piezoelectricity first hand.

Safety Precaution

Materials

2 large quartz (quartzite) crystals, preferably smooth and clear crystals or white quartzite pebbles
safety glasses or goggles
a very dark room or heavy blanket

Procedure ✸ Performing and Recording

1. Put on your safety glasses.
2. Select two pieces of quartz and either enter a darkened room or duck beneath a heavy blanket that does not allow light to penetrate.
3. Strike the two crystals together with a glancing blow.
4. Record your observations.

What Did You Find Out? ✸ Analyzing and Interpreting

1. What did you observe when the crystals were hit together?
2. Using your knowledge of piezoelectricity, attempt to explain your observations.
3. Describe a known application for what you have seen or invent an application of your own.

Electricity to Light

Using electricity to produce light seems like a pretty simple matter. In incandescent light bulbs, a filament made of a high-resistance metal glows brightly when an electric current passes through it. In fluorescent or neon bulbs, the electric current causes a gas or vapour to glow brightly. Piezoelectric crystals can produce light when they are hit together.

Some recent types of flashlights, bicycle lights, and toy lights do not have a light bulb. Instead they have light-emitting diodes (LEDs), solid-state electronic components that glow when electricity flows through them. LEDs use only a fraction of the power of a traditional bulb and last for years as opposed to months. How do they work? The heart of the LED is a tiny semiconductor chip that is often protected by a transparent plastic case. Unlike regular light bulbs, LEDs work only when connected to a circuit in one direction.

Figure 4.27 The plastic package of this light-emitting diode is about the size of a grain of rice, but all the light is produced from a microscopic area in the centre of the package.

DidYouKnow?

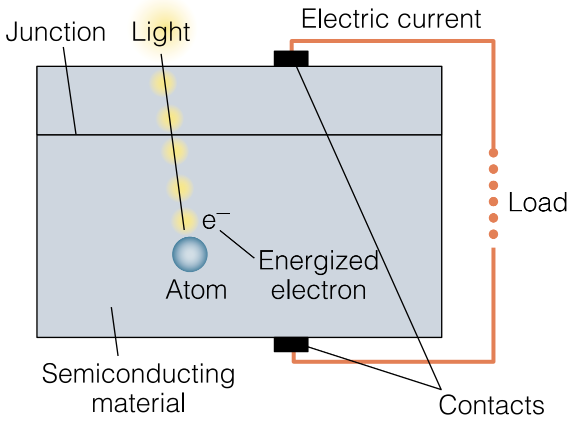
Thousands of miniature LEDs form the liquid-crystal and flat-panel displays used in many portable computers and hand-held "digital assistants." The displays use organic light-emitting liquids, which emit light when an electric current passes through them. The colour of light emitted depends on the particular type of material used. In order to observe the light emitted by an organic LED, at least one of the electrodes must be transparent.

Light to Electricity

As traditional methods of producing electricity are becoming more expensive and causing increased concerns about pollution, using light to produce electricity could play a large role in our future (see figure 4.28). The *International Space Station* is powered entirely by an electricity-generating solar array that will eventually cover an area of approximately 0.5 ha.

The device that is most commonly used to produce electricity from light is called a photovoltaic (PV) cell, or solar cell. Photovoltaic cells are made of semiconducting materials such as silicon. When light strikes the cell, some light is absorbed by the semiconductor material, breaking electrons loose and allowing them to flow freely. Metal contacts on the top and bottom of the PV cell allow this electric current to be drawn off for external use in devices such as calculators, water heaters, or emergency roadside telephones. Because voltage and current of an individual cell are limited, solar cells are usually combined to form modules, which are in turn combined to form arrays.

Figure 4.28 Light hitting an individual photovoltaic cell transfers energy to electrons, starting a current through the load. A rooftop solar array can power a house.



Find Out **ACTIVITY**

Show Me the Light!

How much electricity can be produced by photovoltaic cells (solar cells)? What factors affect the output of a photovoltaic cell? Investigate these questions as you perform this activity.

Materials

1–3 small photovoltaic cells
ammeter or milliameter
plug-in light source
wires with alligator clips
meter stick
protractor

Safety Precautions

If your light source uses an electric bulb, handle it carefully. Light bulbs are fragile and can get hot enough to burn you.

Initiating and Planning
Performing and Recording

Procedure

1. Work with your group to formulate a hypothesis that identifies one factor that you think affects the amount of current produced by a photovoltaic cell or cells. Predict how the current will change when this factor increases and decreases.
2. Design a simple investigation to test your hypothesis. Then carry out the investigation using the materials supplied.
3. Collect results from at least two other groups that investigated different factors.
4. Record your results and the results collected from your classmates in an appropriate format.

Analyzing and Interpreting

What Did You Find Out?

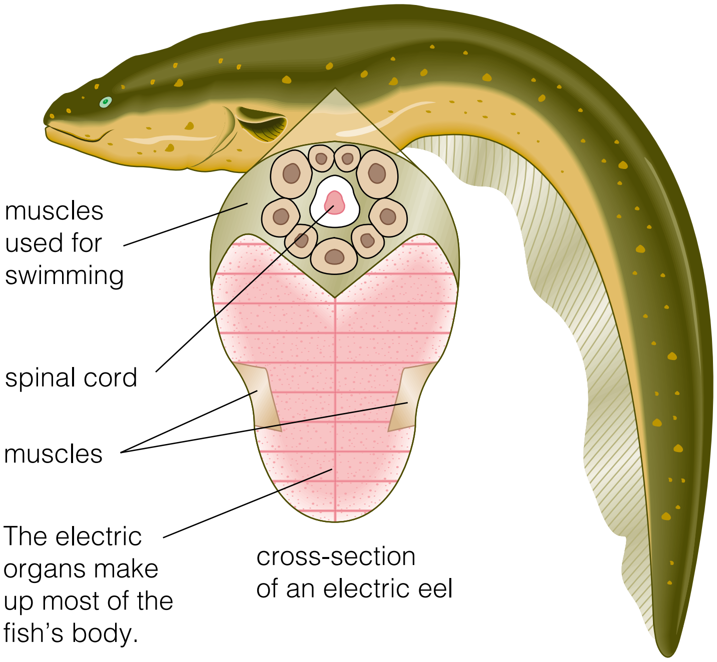
1. For the investigation carried out by your group, what were the manipulated and responding variables?
2. What were the manipulated variables in other groups' investigations?
3. Based on your findings, which variable or variables had the greatest effect on the electrical current produced by the cell? Suggest a reason why.
4. In addition to the factors investigated by groups in your class, name at least three other factors that might affect the ability of a photovoltaic cell to produce electricity.

Extension

5. Based on the data you collected, describe features you would include if you were to design a home powered by photovoltaic cells.
6. What are the main reasons why some people *are* currently choosing photovoltaics as a home power source, and the main reasons why other people *are not* using solar power?

DidYouKnow?

Many fish have electric organs that can produce a large voltage. They use this electric energy to detect enemies, navigate, and possibly to communicate. These animals are said to be electrogenic and electroreceptive. The South American fresh water eel, *Electrophorous electricus*, can generate the largest voltage of any fish. The electric organ consists of thousands of flat, specialized muscle cells, called electroplaques, which make up about 40% of the eel's mass. Each cell generates a voltage of about 0.15 V. Because the cells are connected in series, the electric organ can generate a total voltage of about 600 V. The eel releases a burst of electric energy, lasting about 3/1000 of a second, to stun prey. This "electric shock" causes the prey to stop breathing and drown. Then the eel consumes its meal.


muscles used for swimming
spinal cord
muscles
The electric organs make up most of the fish's body.
cross-section of an electric eel

TOPIC 4 Review

1. Describe at least three ways in which usable light can be produced from electricity.
2. How does a thermocouple work? Give two examples of uses for thermocouples.
3. What happens to a piezoelectric crystal when it is squeezed? Give one example of how this phenomenon can be applied.
4. What would happen if an electric current were passed through a piezoelectric crystal? Describe an application for this phenomenon.
5. Photovoltaic cells produce electricity from light. Describe two concerns or problems a homeowner might face in a house powered entirely by photovoltaics.

TOPIC 5 Portable Power

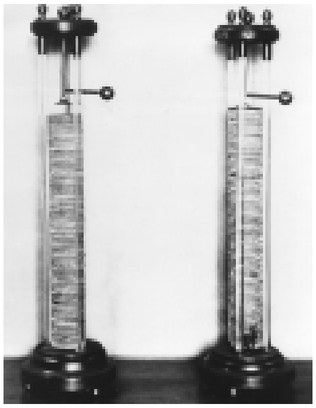


Figure 4.29 "Voltaic piles" like these, invented in 1800, were the first electric batteries.

How many battery-powered devices are in your household? How many batteries do you buy each year in order to transform chemical energy directly into electricity? Worldwide, people buy over 15 *billion* batteries annually. Luigi Galvani (1737-1798), who noticed that a frog's muscle would twitch when touched by two different metals, could hardly have imagined this outcome of his observations.

Galvani believed that the frog's tissues had a unique ability to generate "animal electricity." Later, Alessandro Volta (1745–1827) showed that a voltage could be generated without using living tissue by placing different metals in a solution containing a salt or acid. Today, such a device is called an **electrochemical cell**. You may recall from Topic 2 that a battery is just a series of connected cells.

Find Out ACTIVITY

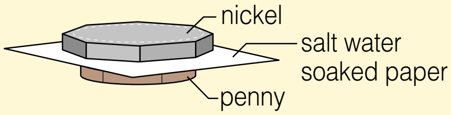
Pile of Power

Volta invented a battery composed of alternating layers of zinc, blotting paper soaked in salt water, and silver. In this activity, you will recreate Volta's design using common materials.

Materials

pennies, nickels, dimes
other coins
copper wires with alligator clips
voltmeter
scissors
paper towels
saturated salt water solution

Safety Precautions



Procedure

Performing and Recording

1. Cut circles about the size of a nickel out of the paper towel and soak them in the salt solution.
2. Construct a single cell as shown in the diagram.
3. Press wires from the voltmeter to the top and bottom coins in the pile. Record the voltage produced.
4. Add another penny and nickel layer to form a two-cell battery. Record the voltage produced.
5. Repeat steps 3 and 4 using more cells, a different arrangement of cell components, or a different combination of coins.

What Did You Find Out?

1. What components and conditions are essential for a cell to operate?
2. Based on your findings, what factors affected the voltage of your battery most?
3. Suggest at least three things you could do to make your battery produce even higher voltages.

Electrochemical Cells

In any electrochemical cell, two metal **electrodes** are surrounded by an **electrolyte**, a substance that can conduct electricity. “Wet cells” use a liquid electrolyte. Car batteries contain several wet cells. “Dry cells,” such as those pictured in Figure 4.31, have a paste, plastic, or ceramic solid electrolyte.

Figure 4.30 shows the arrangement of parts in a typical aluminum-copper wet cell, as it could be set up in a laboratory. When the cell supplies current to a circuit, atoms of aluminum become ions and go into the electrolyte solution. As a result, the aluminum strip slowly disintegrates. A similar process occurs in every electrochemical cell: one electrode is consumed as the cell operates. Common “dry cells” sometimes leak when their zinc case, which forms one electrode, is eaten away and the electrolyte paste oozes out of the cell.

The chemical reactions in a cell determine the potential difference (voltage) that the cell can create. Very few single cells can produce more than 2 V. To obtain higher voltages, batteries contain several cells connected in series (Figure 4.31). If a cell cannot be recharged (a **primary cell**), the amount of chemicals it contains determines the total amount of electric energy the cell can produce. A large “D” cell, for example, contains more chemicals than a small “AA” cell, so the “D” cell has a longer working lifetime than an “AA” cell in an identical circuit. Rechargeable **secondary** cells use chemical reactions which can be reversed. In a recharger, electricity is forced through the “dead” cell, rebuilding the original chemicals and allowing the cell to be reused.

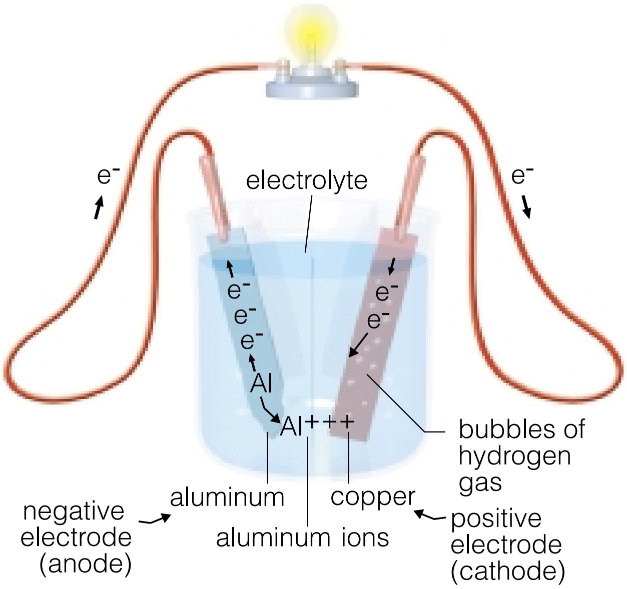


Figure 4.30 Copper and aluminum metal strips are submerged in an acid solution. As electrons move from the aluminum strip to the copper strip through the conducting wire, they light up the light bulb. The circuit is completed by the movement of charged metal ions in the electrolyte.

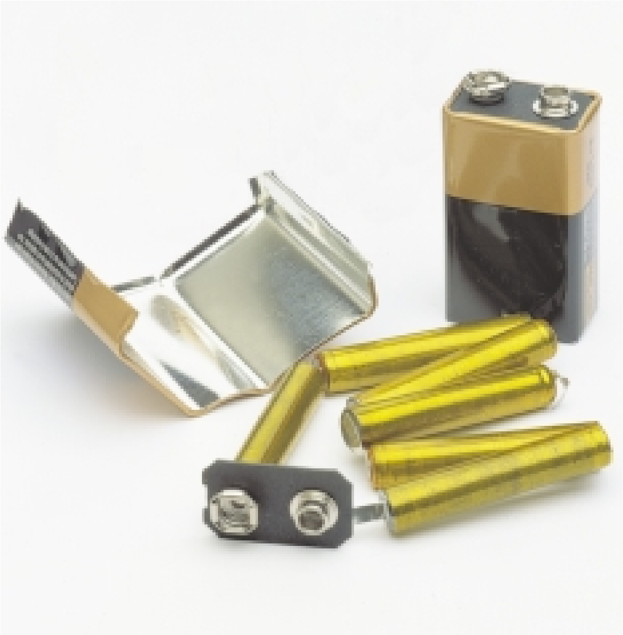


Figure 4.31 A 9 V battery contains six small 1.5 V cells. Are they connected in series or in parallel?

INQUIRY

INVESTIGATION 4-E

SKILLCHECK

- Initiating and Planning
- ✸ Performing and Recording
- ✸ Analyzing and Interpreting
- ✸ Communication and Teamwork

Super Cell Sleuth

In this investigation, you will study several variations of voltaic cells. You will discover factors that enhance or reduce the usefulness of the cells.

Question

What factors affect the voltage and current from a voltaic cell?

Hypothesis

Formulate a hypothesis about which factors you think will affect the voltage and current produced by a voltaic cell.

Safety Precautions

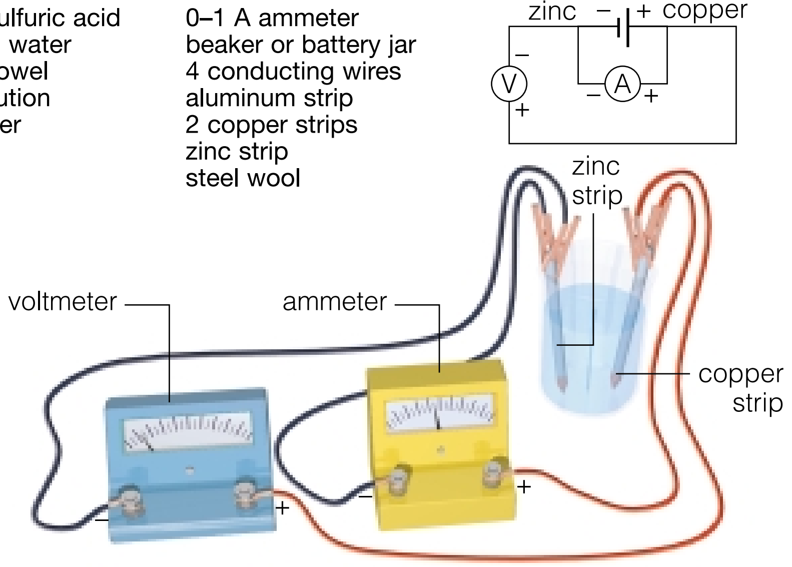
- When handling the metal strips that have been in acid, wear protective gloves and use absorbent paper.
- Inform your teacher if you know you are allergic to latex.
- Sulfuric acid is corrosive. Use only dilute sulfuric acid. If you get acid on your skin or clothing, rinse the area(s) immediately with large quantities of water. Call your teacher at once.

Materials

- latex gloves
- dilute sulfuric acid
- distilled water
- paper towel
- salt solution
- tap water

Apparatus

- 0–5 V voltmeter
- 0–1 A ammeter
- beaker or battery jar
- 4 conducting wires
- aluminum strip
- 2 copper strips
- zinc strip
- steel wool



Procedure

① Make a table as shown below.

② Polish both sides of the metal strips with steel wool.

③ Fill the beaker two-thirds full with dilute sulfuric acid.

Factors Affecting a Voltaic Cell

Factor changed	Metal strips	Solution	Current (A)	Voltage (V)	Action at strips
Initial reading	copper and zinc	sulfuric acid			
After running for 5 min	copper and zinc	sulfuric acid			
Wipe bubbles off	copper and zinc	sulfuric acid			
Change surface area of metals in solution	copper and zinc	sulfuric acid			
Use one new metal strip	aluminum and zinc	sulfuric acid			
Use identical strips	copper and copper	sulfuric acid			
Change solution to water	copper and zinc	distilled water			

④ With separate conducting wires, connect the zinc strip to the negative terminal of the voltmeter and the ammeter. Connect the copper strip to the positive terminals of the voltmeter and the ammeter.

⑤ Check with your teacher to make sure your circuit is wired correctly. Then *carefully* lower the zinc and copper electrodes into the acid solution. Do not let the electrodes or clips on the connecting wires touch.

⑥ Read and **record** the values for current and potential difference. Note and **record** whether bubbles form on either metal strip.

⑦ Allow the cell to operate for about 5 min. Watch for the formation of bubbles on the surface of the metal strips. **Record** whether there are more bubbles on the zinc or on the copper strip.

⑧ Read the meters after the cell has been running for 5 min. **Record** the results.

⑨ Wearing protective gloves, carefully lift the strips from the solution. Wipe away any bubbles from the metal with paper towel. Put the strips back in the acid solution and repeat step 6.

⑩ Once again, wipe away any bubbles from the metal strips. Raise the metal strips so that only half of the length is still in the dilute sulfuric acid. Repeat step 6.

⑪ Remove the copper strip and replace it with an aluminum strip. Repeat step 6.

⑫ Remove both the zinc and aluminum strips and replace them with two copper strips. Repeat step 6.

⑬ Rinse the metal strips with tap water and replace the solution in the voltaic cell with the distilled water. Replace one copper strip with a zinc strip. Repeat step 6.

⑭ Carefully dispose of used paper towel and acid, and clean up acid spills according to your teacher's direction.

⑮ Clean all surfaces and wash your hands thoroughly.

Analyze

1. What variables did you manipulate in this investigation?
2. What was the responding variable in this investigation?
3. What evidence did you observe on the surface of the copper strip to indicate that a chemical reaction was taking place?
4. What happened to the electric current and electric potential difference as time passed?
5. What effect did each of the following actions have on the **(a)** potential difference; **(b)** the current?
   - Removing the bubbles from the surface of the metal
   - Changing the surface area of the metal strips in the solution
   - Using aluminum and zinc instead of copper and zinc
   - Using identical metals
6. Which factors appear to **(a)** determine the potential difference; **(b)** increase the current?
8. Using the copper and zinc strips, which combination of factors produced the largest current?
9. Which pair of metals produced the largest potential difference: copper and zinc or aluminum and zinc?
10. If you were designing a voltaic cell, which combination of metals and conditions would you use? Why?

Extension

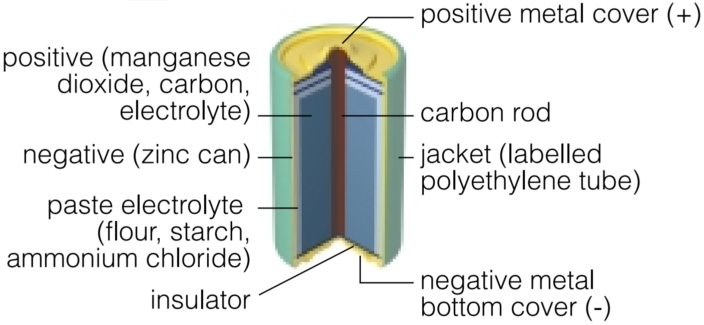
11. Will the voltaic cell still work if the sulfuric acid is replaced with a concentrated salt water solution? Explain. If time permits, ask your teacher for permission to test your prediction.

Types of Cells

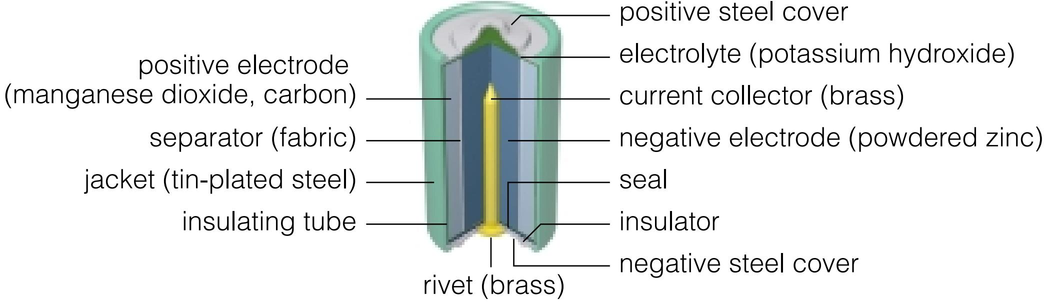
Examine the diagrams below and Table 4.8 to find out more about common types of cells.

Figure 4.32 Modern cells and batteries

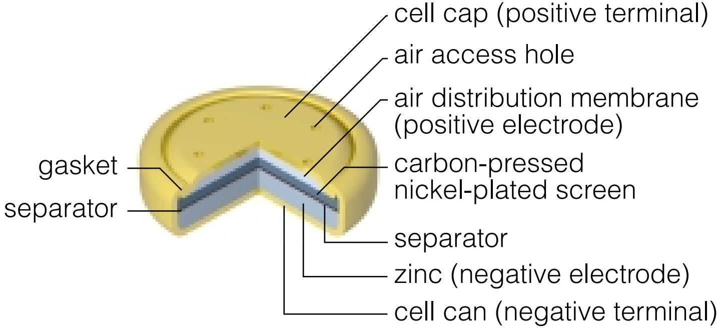
A zinc carbon cell


positive metal cover (+)
positive (manganese dioxide, carbon, electrolyte)
carbon rod
negative (zinc can)
jacket (labelled polyethylene tube)
paste electrolyte (flour, starch, ammonium chloride)
insulator
negative metal bottom cover (-)

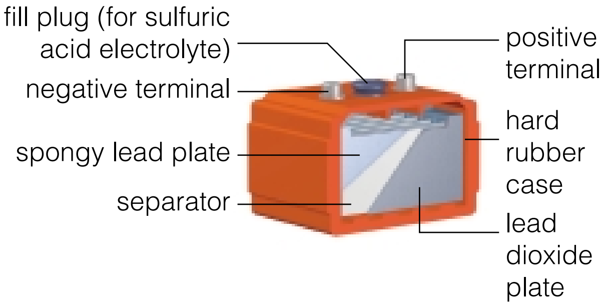
B alkaline cell


positive steel cover
electrolyte (potassium hydroxide)
positive electrode (manganese dioxide, carbon)
current collector (brass)
separator (fabric)
negative electrode (powdered zinc)
jacket (tin-plated steel)
seal
insulating tube
insulator
negative steel cover
rivet (brass)

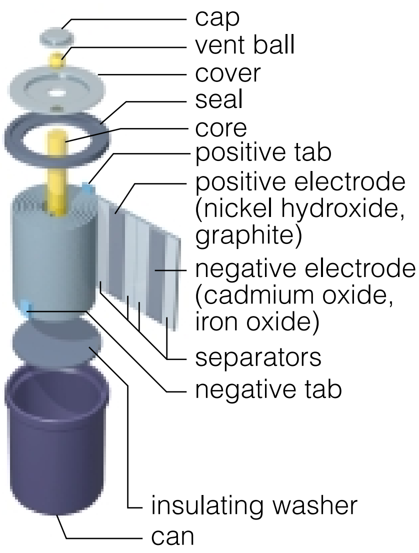
C zinc-air cell


cell cap (positive terminal)
air access hole
air distribution membrane (positive electrode)
gasket
carbon-pressed nickel-plated screen
separator
separator
zinc (negative electrode)
cell can (negative terminal)

D lead acid cell



E nickel-cadmium cell


cap
vent ball
cover
seal
core
positive tab
positive electrode (nickel hydroxide, graphite)
negative electrode (cadmium oxide, iron oxide)
separators
negative tab
insulating washer
can

F nickel-metal hydride

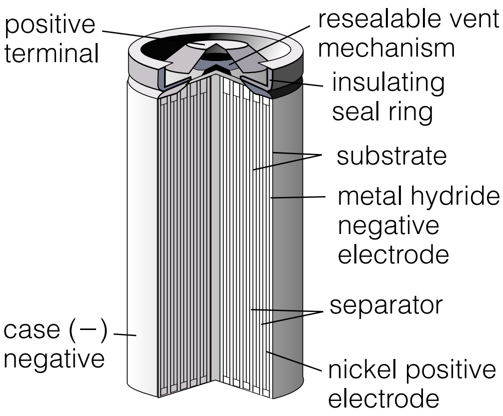

positive terminal
resealable vent mechanism
insulating seal ring
substrate
metal hydride negative electrode
separator
case (−) negative
nickel positive electrode

Table 4.7 Commonly Used Cells and Batteries

Name	Primary/ secondary	Dry/wet	Positive electrode	Negative electrode	Electrolyte	Typical uses	Pros and cons
zinc carbon	primary	dry	manganese dioxide and carbon	zinc	flour, starch, and ammonium chloride	flashlights, portable radios, CD players	not efficient at low temperatures
alkaline	primary	dry	see diagrams	see diagrams	see diagrams	flashlights, portable radios, CD players	last longer than zinc carbon, expensive
zinc air	primary	dry	see diagrams	see diagrams	potassium hydroxide	calculators, hearing aids, watches	highest energy per unit mass, discharges rapidly
lead acid	secondary	wet	see diagrams	see diagrams	see diagrams	cars, motorbikes, snowmobiles, golf carts	dependable, heavy, corrosive liquid
nickel cadmium	secondary	dry	see diagrams	see diagrams	potassium hydroxide	electric shavers, laptop computers, power tools, portable TVs	rechargeable hundreds of times
nickel-metal hydride	secondary	dry	see diagrams	see diagrams	potassium hydroxide	cameras, laptops, cell phones, hand tools, toys	less toxic than NiCad, 40% more energy density than NiCad, rechargeable, no memory effect, lose charge when stored

Find Out ACTIVITY

Select a Cell

Each type of cell has characteristics that suit it to particular uses. You would not use car batteries, for example, to power a portable stereo. Can you choose cells which best suit different applications?

Procedure

Analyzing and Interpreting

1. Make a table with three headings: *application*, *cell features*, and *best cell types*.
2. Decide on desirable features of a cell for each application listed at right.
3. Using information from Table 4.7 and from other reference sources, select the most appropriate type of cell for each use.

Applications

- laptop computer
- electronic wristwatch
- emergency warning light
- child's toy robot
- cave explorer's headlamp
- rechargeable flashlight
- high-powered camcorder light
- hearing aid
- emergency locator beacon
- digital camera

What Did You Find Out?

1. Which type of cell appeared most frequently in your chart?
2. Which type(s) of cells do you use most frequently? For which applications?
3. What other types of electrochemical cells do you know of in addition to the ones described on these two pages?

PROBLEM-SOLVING

INVESTIGATION 4-F

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Building a Battery

Now that you understand how a battery operates, use your knowledge to create a battery using several dry cells in different combinations. Connect dry cells in several different arrangements.

Challenge

Assemble and test different combinations of individual dry cells to create a battery that will light a bulb most brightly.

Design Specifications

A. All batteries must use two or three individual cells.

B. The dry cells can be placed in series or in parallel or both.

C. The results of your tests should be recorded in a table such as the one below. For each trial, draw a diagram using the proper number and arrangement of cell symbols to show how the battery was constructed.

Safety Precaution

Cells in Series and in Parallel	Voltage (V)	Brightness of bulb (same, brighter, dimmer)
One cell		standard for comparison
Two cells in series		
Three cells in series		
Two cells in parallel		
Three cells in parallel		
Series batteries with one cell reversed		

Plan and Construct

① With your group, predict which arrangement of cells will produce the most powerful battery.

② Lay out the circuit illustrated below. Make sure the positive (red) terminal of the voltmeter is connected to the positive terminal of your battery.

③ Measure and record the voltage across the dry cells.

Evaluate

1. Which of your batteries lit the bulb most brightly?

2. Is there any relationship between the voltage of the battery and the brightness of the bulb? If there is, write a statement describing the relationship.

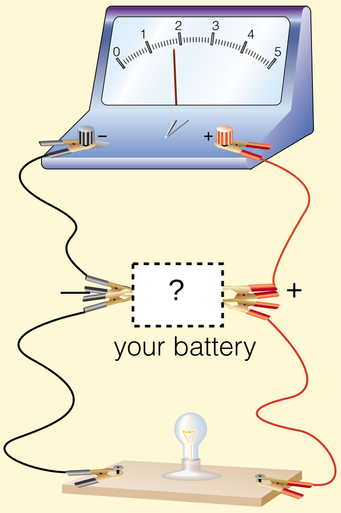
3. Write a statement that describes any advantage gained by putting two or more cells

(a) in series with each other

(b) in parallel with each other

(Be sure to include information about voltage and current in your answers.)

4. How did you reach your conclusions about current when you did not use an ammeter?



5. Explain what happened when the three cells were connected with the third in a direction opposite from the first two.

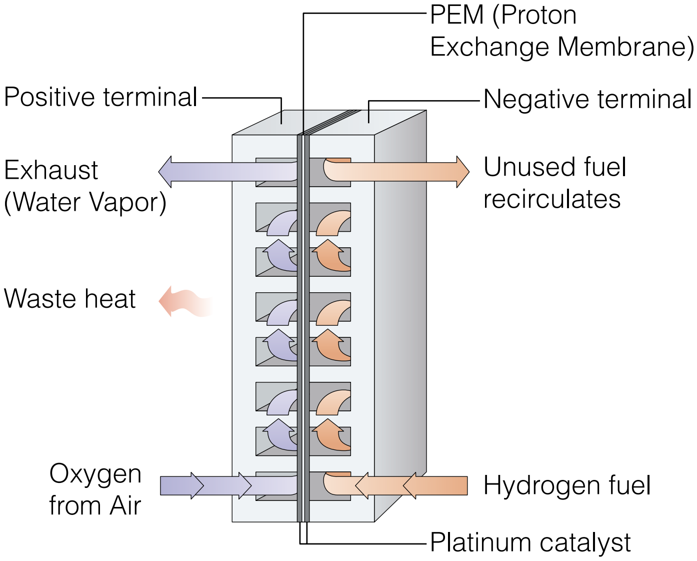
Across Canada

Automobile companies are investing millions of dollars to develop electric vehicles powered by fuel cells, instead of traditional batteries. Ballard Power Systems, in Burnaby, B.C., is a world leader in fuel cell technology. The company was established in 1979 to research and develop high-energy lithium batteries. By 1983, Ballard's engineers were developing, manufacturing, and marketing proton exchange membrane (PEM) fuel cells. Today, the company is working with other world leaders in fuel cell technology to create products for the mass market.

Ballard Power System's technology allows the production of efficient, environmentally friendly power sources for automobiles, electric equipment, and portable power production. This company's fuel cells boast zero emissions of harmful chemicals. To create electricity, Ballard's fuel cells combine hydrogen and oxygen without combustion. Electricity, heat, and pure water are the only by-products of the fuel cell's reaction. Unlike other electrochemical cells, fuel cells are not limited by the supply of chemicals inside them. As long as the proper fuel is supplied, the cell continues to produce electricity.

Another benefit of fuel cells is their efficiency. Proton-exchange membrane fuel cells are 50–85% efficient. Traditional automobile engines are only 25–40% efficient and emit harmful pollutants into the atmosphere.

Ballard Power Systems, along with international companies including DaimlerChrysler, Ford, GPU International, and ALSTROM, are working together to make Ballard fuel cells more readily available. Developing an efficient, inexpensive, and non-polluting source of hydrogen fuel for the cells is one focus of current research.



TOPIC 5 Review

1. What are the main components in a voltaic cell? Describe the function of each component.
2. How do batteries differ from cells? What arrangement of three cells will result in the greatest electric current? Which arrangement would result in the greatest longevity for the battery?
3. Describe three factors within a voltaic cell that you could manipulate in order to produce a cell with the highest possible voltage. For each factor describe how you would manipulate it.
4. Explain the difference between
   (a) wet cells and dry cells
   (b) primary and secondary cells
5. Describe the advantages and disadvantages of using fuel cells compared to other types of electrochemical cells.

Wrap-up TOPICS 4–5

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

electric energy
heat
thermocouple
thermo-electric generator
thermopile
piezoelectric effect
photovoltaic cell (PV)
electrodes
electrolyte
fuel cell

Reviewing Key Terms

1. In your notebook, write the key term that best matches each of the following words or phrases.

(a) a form of energy that is always transferred from a warmer substance to a cooler one (4)

(b) device that converts heat to a small amount of electric energy often used in temperature sensors. (4)

(c) a push-button barbeque lighter produces a small electric current (4)

(d) thermocouples combined to produce greater amounts of electricity (4)

(e) a device, usually composed of silicon, that can be used to produce electricity from light (4)

(f) different types of metals in a voltaic cell that have different attractions for electrons (5)

(g) a substance that can conduct an electric current through the movement of ions (5)

Understanding Key Concepts

2. Identify three devices that convert electrical energy into light, and give an advantage and disadvantage of each one. (4)

3. Copy the diagram of the thermocouple into your notebook. Add labels and arrows to show the key parts and movement of charge. (4)

4. Describe an advantage of thermocouples over regular liquid thermometers. (4)

5. Why are thermo-electric generators most often used in remote locations? (4)

6. What was Luigi Galvani's hypothesis about "animal electricity?" Did Volta's "pile" support that hypothesis? (5)

7. For each of the following voltaic cells, describe whether it would produce a voltage. Explain your reasons for each prediction. (5)

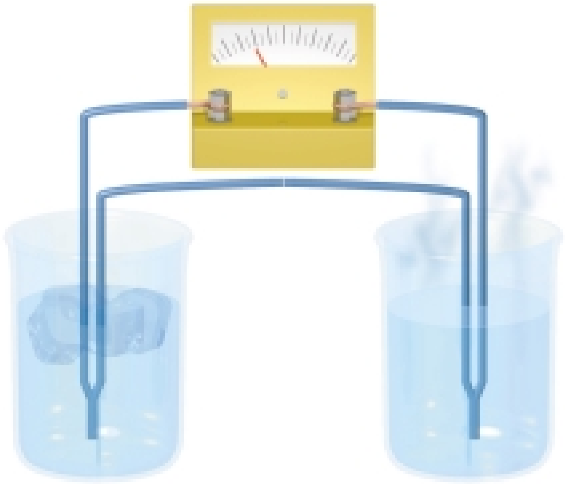
(a) a cell with copper and zinc electrodes in an acid electrolyte

(b) a cell with two copper electrodes in a salt water electrolyte.

(c) a cell with zinc and carbon electrodes in a distilled water electrolyte

8. If two D-cells are connected positive end to positive end, how much voltage would a voltmeter across the total array indicate? Give a reason for your response.(5)

9. Describe at least two possible benefits and two possible drawbacks of passing a law requiring that all new cars be powered by electricity generated by fuel cells. (5)



TOPIC 6

Generators and Motors

Imagine depending on battery-powered flashlights to light a sports field for a night game. Not likely? Batteries are fine for portable power, but they cannot supply the quantities of electricity required for outdoor lighting equipment, heavy appliances, and large industrial machinery.

Most of our electricity comes from the conversion of mechanical energy. Mechanical energy is associated with any system with moving parts — for example, a rotating windmill, spinning turbines in thermo-electric, nuclear, or geothermal power plants, or the moving water of rivers of tides. A device that converts mechanical energy into electric energy is called an **electric generator**. The operation of a generator depends on a relationship that surprised early scientists — electricity and magnetism are related.

Find Out ACTIVITY

Electric Current-Generating Tube

Using a magnet and a coil of wire to produce an electric current is the basic principle of electric generators. In this Activity you will have the opportunity to investigate factors that affect the current produced by a simple generator.

Materials

5 m of insulated copper wire (about 26 gauge)
cardboard tube
galvanometer or milliammeter
ammeter
powerful bar magnet

Procedure

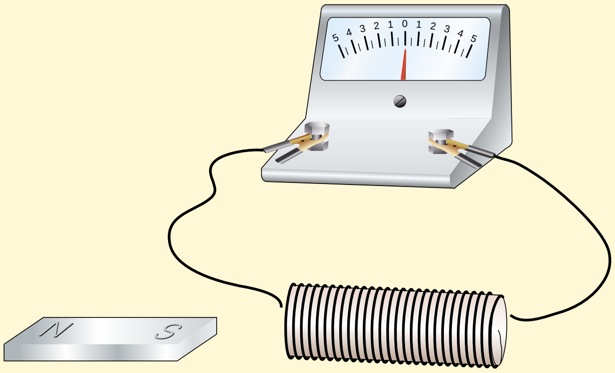
Performing and Recording

1. Leaving about 15 cm for a lead at the end of the wire, make a coil of about 25 turns by wrapping the wire around the cardboard tube. Remove the tube from the coil.

2. Strip the insulation off each end of the wire. Then connect the wire to the ammeter.

3. While closely monitoring the meter, insert one end of the bar magnet into the coil of wire and then pull it out. Record any movement of the meter needle that you observe.

4. Next, record the effect on the meter needle when you:
   - **(a)** vary the speed with which you move the magnet inside the coil of wire
   - **(b)** vary the speed with which you move the magnet over the outside of the coil
   - **(c)** move the coil over the magnet while the magnet remains still
   - **(d)** move the magnet ouside the coil in different directions



What Did You Find Out?

Analyzing and Interpreting

1. How does the magnet's speed affect the current that is produced?

2. How does the position of the coil or magnet affect the current produced?

3. What combination of conditions generates the largest current?

Figure 4.33 Hans Christian Oersted (1777–1851) was a Danish physicist who wanted to show that there was no relationship between electricity and magnetism, but he observed just the opposite.

Electricity to Magnetism

The idea for the first electric generators dates back to a discovery by Hans Christian Oersted and André-Marie Ampère in 1820. They noticed a relationship between electricity and magnetism. Oersted observed that a compass needle turned when it was near a wire carrying electric current. The amount of deflection depended on how much electric current was flowing in the wire. When the direction of the current was reversed, the needle of the compass moved in the opposite direction. As soon as the current was interrupted, the magnetic effects ceased.

Electromagnets

When a soft iron core is inserted into a coil of wire and a current is passed through the wire, an even stronger temporary magnet called an **electromagnet** is created (see Figure 4.34). When electric current flows in the coil, one end of the core becomes a magnetic north pole and the other the south pole. When more coils of wire are wrapped around the iron core, the strength of the magnet increases. Increasing the current also results in a stronger magnet. If the direction of the current is reversed, the polarity of the magnet is also reversed. When the current is turned off, the iron core loses its magnetic properties.

The strength of an electromagnet depends greatly on its core material. Iron cores are much more effective than other metals, wood, or plastics at producing strong electromagnets.

Michael Faraday (1791–1867) is credited with discovering the basic principles of electromagnetism. Faraday became interested in chemistry and physics while reading science texts as he apprenticed as a bookbinder. At 21, he was accepted as a laboratory assistant to chemist Humphrey Davy. Faraday's experiments form the basis of modern electromagnetic technology and electrochemistry. He introduced terms such as "ion," "electrode," "cathode," and "anode" to science, and invented the idea of lines of magnetic force. The farad, the unit for stored electric charge, is named in his honour.

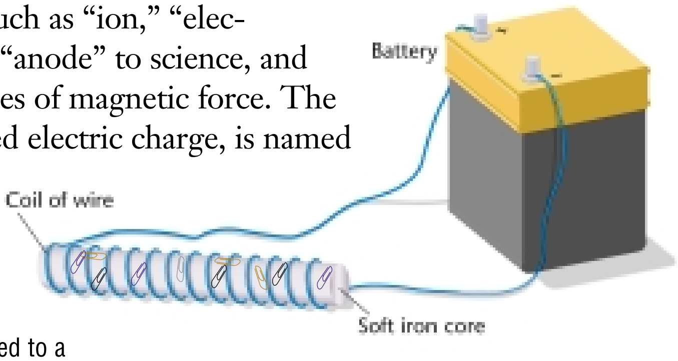
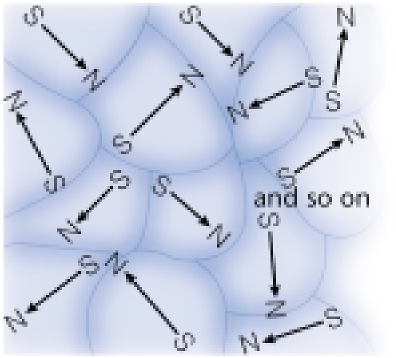
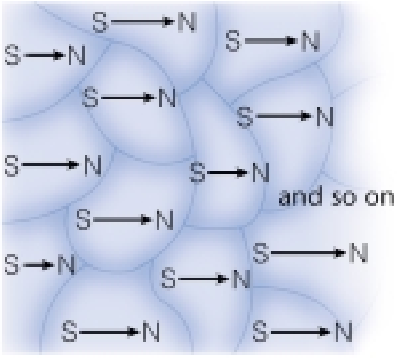


Figure 4.34 A simple electromagnet consists of an electric power source connected to a wire coiled around a soft iron bar.



unmagnetized material



magnetized material

DidYouKnow?

Individual atoms behave like tiny magnets, each having a north and south pole. Atoms in materials like iron, cobalt and nickel, group together into *magnetic domains*, in which all the north poles face the same way. Unmagnetized objects have domains that are randomly arranged. Their magnetic effects cancel out. Domains in a magnet or electromagnet, however, are aligned, so the resulting magnetic effects are strengthened. Magnetic domains in iron line up very easily, so iron is an effective core for electromagnets.

PROBLEM-SOLVING

INVESTIGATION 4-G

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

The Attractive Electromagnet

Using the basic principles upon which electromagnets operate, you can produce surprisingly strong magnetic effects. In this investigation you will assemble and test a circuit that creates and controls a strong electromagnet.

Challenge

Using the materials supplied, design an electromagnet that will allow your group to transport the largest possible number of metal objects a specified distance in a fixed time.

Apparatus

5 cm iron nails
10 cm iron nails
paper clips
iron bolts and nuts
straight pins
1.0 m and 0.5 m lengths of insulated copper magnet wire, such as #26 AWG
D-cells (2 per group)

Safety Precautions

Design Specifications

A. The D-cells and wire may be used to construct one or two electromagnets.

B. You may use either a single 1.0 m length, or two 0.5 m lengths of magnet wire.

C. Your electromagnet(s) may be constructed from any or all of the supplied materials.

D. Each group will have 2 min to lift and transport as many metal objects as possible from a table, across a 4 m space, and into a collecting container, using only their electromagnet(s).

E. You may not touch the metal objects with your hands to help your electromagnet lift, transport, or drop them.

Plan and Construct

① With your group, plan and then construct your electromagnet.

② Plan how to use your electromagnet to pick up, transport, and drop metal objects. Test your strategy and modify it if necessary.

③ Test your electromagnet as your teacher directs.

Evaluate

1. Calculate the total number of points your electromagnet earned during its trial.

Metal object	Point value
straight pin	2
paper clip	4
iron nut	8
iron bolt	12

2. How did you make your electromagnet as powerful as possible?

3. How did you release objects from the electromagnet? How effective was this method? How could it be improved?

Extend Your Skills

4. If your school has computer probeware, develop and test an alternative way of measuring the strength of your electromagnet. You may wish to use a force probe or a magnetic field sensor.

Magnetism to Electricity

Experiments such as the one you have just done show that magnetic effects can be produced by electric currents. The opposite process is also possible. Electric effects can be produced using a magnet, as you observed at the beginning of this Topic. Michael Faraday and an American scientist named Joseph Henry made this discovery in 1831. Working independently, they found that a voltage developed in wires that were moved at an angle to a nearby magnet. The same thing happened when the magnet moved at an angle to a stationary wire. If the motion stopped, or if the magnet and wire moved parallel to each other, no voltage developed.

Faraday and Henry extended their experiments by connecting the wire to a load. Now an electric current flowed in the circuit, but only as long as either the wire, or the magnet, or both were moving (Figure 4. 35). Wrapping the wire into a coil around the magnet increased the current, as you have observed.

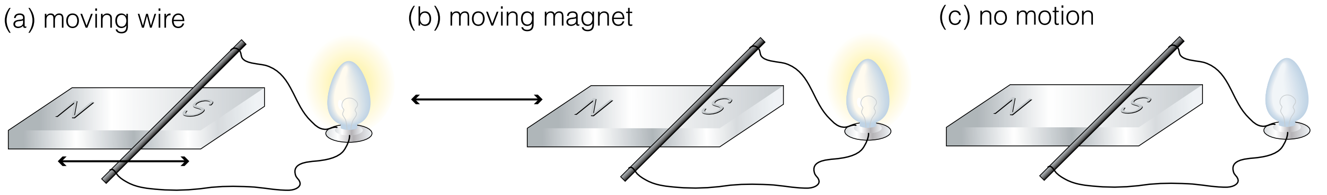


Figure 4.35 Relative motion between a wire and magnet causes a current to flow in a circuit connected to the wire.

Today, we say that a potential difference (voltage) is "induced" in a wire when there is relative motion between the wire and a nearby magnet. When the wire is connected to a circuit, an "induced current" flows. This connection between magnetism and electricity was used to develop motors, generators, and other electrical technology long before scientific theories were developed to explain the relationship.

Cool Tools

Current-carrying coils around this experimental Tokamak nuclear fusion chamber turn it into a gigantic electromagnet. Gas molecules with a temperature of more than 10 000 000°C are suspended and compressed by the magnetic effects.

Extremely powerful electromagnets have many other uses. Experimental maglev (magnetic levitation) trains use the repulsion between electromagnets on the train cars and electromagnets mounted between the tracks to suspend the entire train above the track, reducing friction and increasing efficiency.

In hospitals, patients are wheeled inside gigantic electromagnets in MRI (magnetic resonance imaging) equipment. As atoms in the patient's body are twisted by the powerful magnets, they emit radio signals that can be detected, analyzed, and assembled into images by computer. MRI equipment can produce detailed images of soft body tissues that cannot be examined using X rays.

What's in a Generator?

This AC generator, the most common form, has a coil of wire that rotates inside a stationary field magnet (see Figure 4.36). The coil is rotated by an external force, which is usually supplied by steam, falling water, or wind. Most large generators use electromagnets rather than permanent magnets.

As wires in the coil rotate, electrons begin to move along the wire in one direction. After one-half revolution of the wire loop, each side of the coil passes near the opposite pole of the magnet. The electrons in the coil start moving in the other direction. The direction of the current from the generator changes twice with each revolution. Electricity produced by this type of generator is called **alternating current** (AC) because it changes direction, or "alternates" (see Figure 4.37).

In North America, generators turn at a controlled speed, providing alternating current that changes direction 120 times per second. On a graph, the current has a wave shape, with 60 complete waves each second, so we describe it as 60 Hertz (60 Hz), or 60 cycle AC.

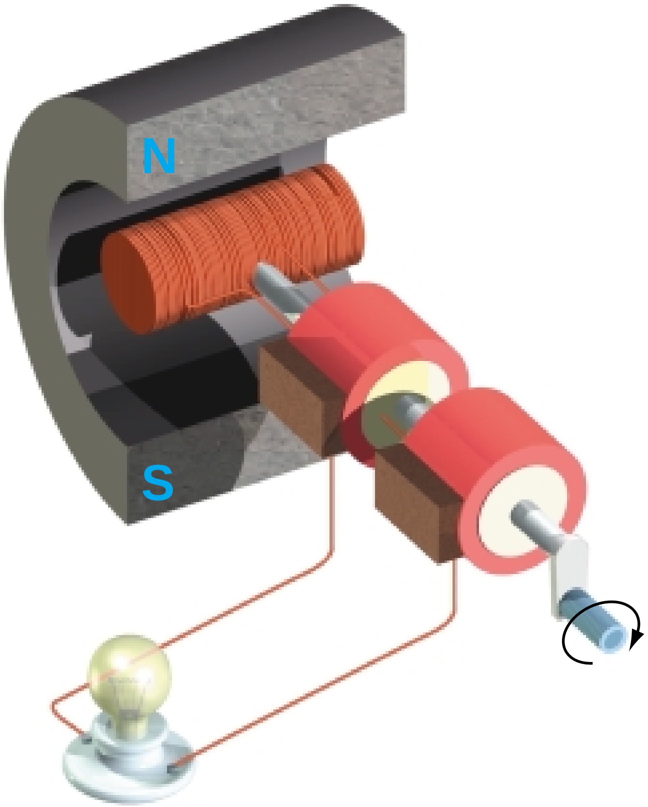


Figure 4.36 In this AC generator, electric current is produced when a coil of wire is rotated inside a magnet. (As you know, current can also be produced when a magnet is rotated within a coil of wire.) In this hand-cranked model, everything attached to the shaft rotates as a unit.

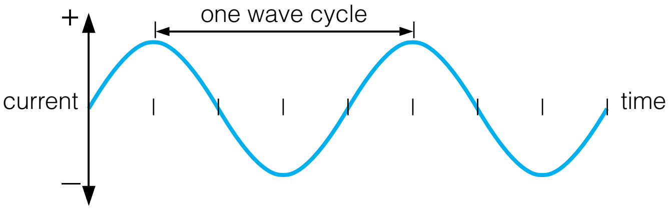


Figure 4.37 Current from an AC generator constantly varies in size and direction. Positive and negative values on the graph represent the opposite directions of the current flow.

Word **CONNECT**

Generators that produce alternating current are also called *alternators*. Car electrical systems often use an alternator to generate AC, which is then converted to direct current for the motor's ignition system. Multiple choice tests present you with several *alternative* answers. A sports team may have practices and games on *alternate* nights. What is the common feature of words and phrases based on "alternate"?

Why do most power plants produce alternating current rather than direct current? One reason is that it is relatively easy to increase or decrease the voltage of alternating current. In order to travel long distances efficiently through transmission lines, the voltage is increased. For consumer use, voltage must then be decreased. This process involves transformers, which will be discussed in more detail in the next Topic.

DC Generators

Generators can also produce direct current (DC), or current in only one direction. A generator that produces direct current is often called a **dynamo**. In a dynamo, the armature (rotating loop of wire) is connected to the outside circuit by a split-ring **commutator** (Figure 4.38A).

To visualize how the commutator operates, study the four parts of Figure 4.38B. (The red dot on the armature lets you track its rotation.) In position 1 the brushes touch the metal split rings, so electrons flow from and return to the armature. When the armature and commutator rotate to position 2, insulating gaps in the commutator momentarily stop the electric current. As the gaps move past the brushes, current resumes (position 3). At this point, the direction of charge flow in the armature has reversed, but so has the connection through the commutator. As a result, current continues through the load in a constant direction. The same sequence of events repeats continuously as the armature keeps rotating past position 4.

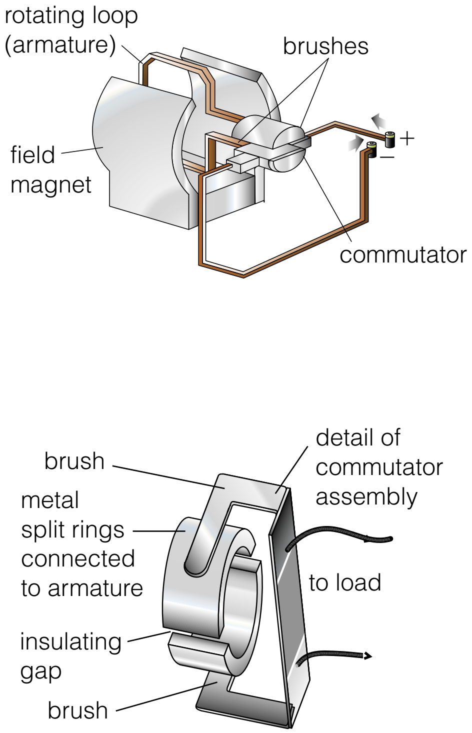


Figure 4.38A A typical DC generator has a split-ring commutator so it sends current through a circuit in only one direction.

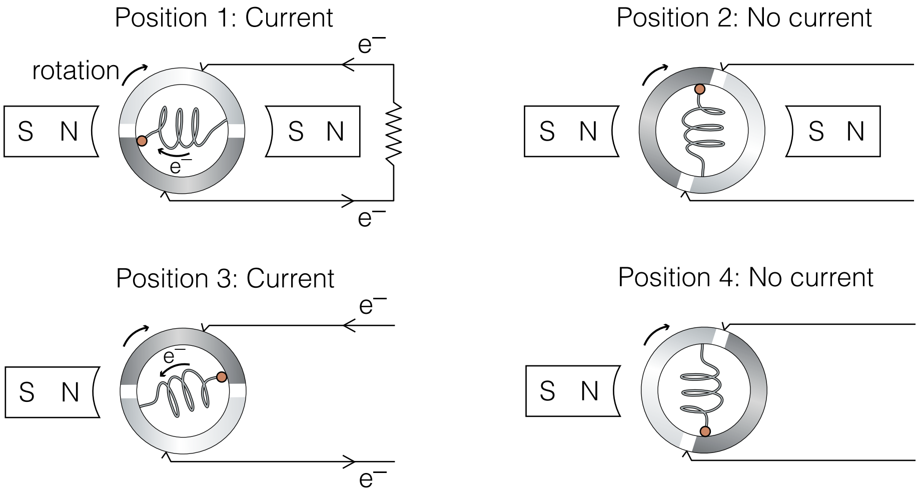


Figure 4.38B These end views of the DC generator in Figure 4.38A show the changing position of the two halves of the commutator. Current through the load is not constant, but it is one-directional.

DidYouKnow?

The current electricity that is produced by a DC generator is not the same as that produced by a battery. Although both devices produce an electric current in one direction only, the DC produced by the generator is pulses of current that coincide with the spinning of the generator. Batteries produce a smooth continuous current.

Electric Motors: Electric to Mechanical Energy

An electric motor can be constructed in exactly the same way as a generator. Instead of *producing* electricity, however, a motor *uses* electric energy to make a coil of wire spin between the poles of a magnet (the "field magnet"). This occurs because the coil (armature) is connected to a source of electric energy. Current flowing through the coil turns it into an electromagnet, which is rotated by magnetic forces from the field magnet. The fundamental law of all magnets — opposite poles attract and like poles repel — is the basis upon which electric motors function.

DC Motors

In one common design for DC motors, a rotating wire coil (an armature) becomes an electromagnet as current flows into it through a split-ring commutator. The armature is attracted and repelled by stationary field magnets near it, so it begins to rotate. The commutator acts as a switch, cutting off and then reversing the direction of current flow to keep the armature turning.

- electrons flow to the right from the battery to the commutator into the armature
- the north pole of the armature is repelled by the top of the field magnet and attracted by the bottom of the field magnet
- the armature begins to rotate clockwise (the yellow dot lets you follow the rotation)

- the commutator cuts off the current so the armature does not stall as it passes close by the field magnets
- the momentum of the spinning armature keeps it moving clockwise

- the commutator reverses the direction of current through the armature
- the ends of the armature reverse their magnetic polarity
- the top of the armature is again repelled by the top of the field magnet and attracted by the bottom of the field magnet
- the force on the armature continues to rotate it clockwise

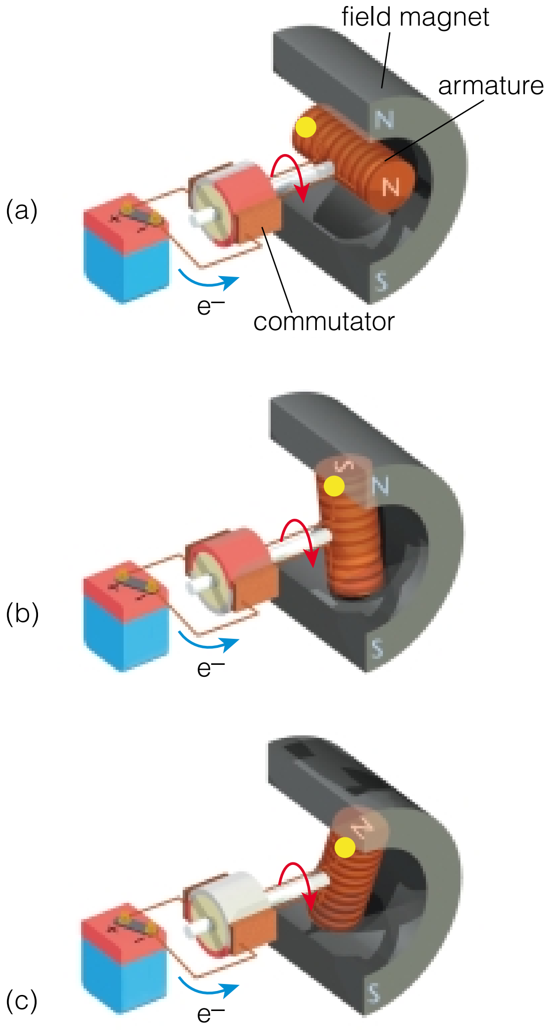


Figure 4.39 A DC motor is rotated by magnetic forces between the field magnets and the armature, which acts as an electromagnet.

PROBLEM-SOLVING

INVESTIGATION 4-H

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Let's Get Motoring!

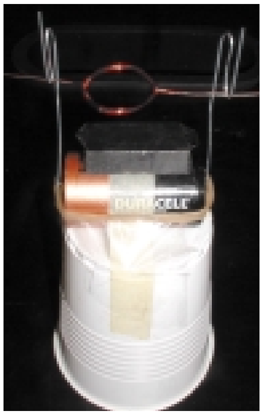
The principles by which an electric motor works are relatively simple. Constructing one from simple components can be tricky. At times, you may find you need to fine-tune certain components in order to ensure your motor works.

Challenge

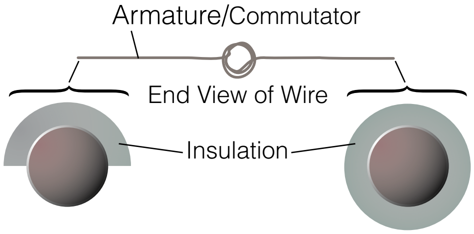
Following the specifications, construct a working electric motor using only the simple materials supplied. Troubleshoot and adjust your motor until it meets the design specifications.

Apparatus

1 D-cell
2 large paperclips
1 wide rubber band
1 plastic, paper, or Styrofoam™ cup (250 to 500 mL)
60 cm of enamel-coated magnet wire
1 rectangular or round ceramic magnet (about 1 cm thick and at least 3 cm long)
2.5 cm diameter wooden dowel or broom handle
masking tape
fine sandpaper



Note: You can make a split-ring commutator by removing insulation completely from one end of the coil wire. At the other end, remove insulation from around only half the wire, as shown.



Safety Precautions

Design Specifications

1. You can use only the materials supplied.
2. Your motor must run continuously for at least 10 s.

Plan and Construct

① Decide how you will construct your motor, using the illustrations as a guide.

② Build the motor and test it. Modify the motor until it operates successfully.

③ Draw a scientific diagram of your motor, labelling each part and the material used to build it.

Evaluate

1. Score your motor's success using the table below.
2. Describe problems you encountered in this activity and the steps you took to overcome them.

Extend Your Skills

3. Based on your experience in this investigation, make a list of at least four troubleshooting instructions that would assist students constructing this motor in the future.

	Evaluation Criteria	
Level of success	Criterion	Score Points
1	coil moves but does not rotate	1
2	coil rotates less than one-half turn	2
3	coil rotates one-half to one turn	5
4	coil rotates more than one turn but for less than 10 s	7
5	coil rotates continuously for 10 s	10

AC Motors

Electric motors found in larger appliances, such as dishwashers, washing machines, garage door openers, and furnaces, operate on alternating current. AC motors have a rotating core, or **rotor**, made up of a ring of non-magnetic conducting wires connected at the ends and held in a laminated steel cylinder. Surrounding the rotor is a stationary component called a **stator**. In its simplest form, the stator is a two-pole (north and south) electromagnet. More complex stators resemble a ring of many electromagnets, each with a north and south magnetic pole. When an AC motor is turned on, the attraction and repulsion between the magnetic poles of the stator and the rotor causes the rotor to spin.

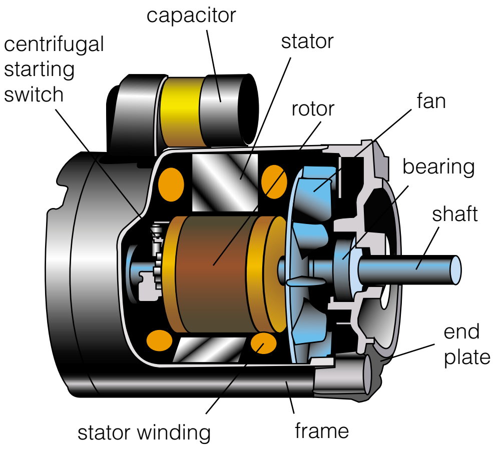
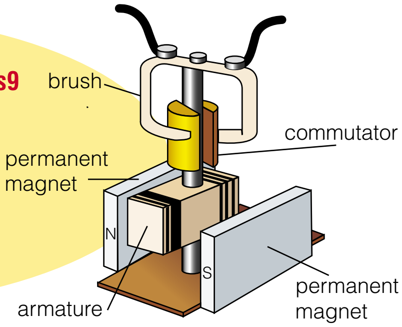


Figure 4.40 AC motors such as this one are used in a variety of larger appliances.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

The St. Louis motor was designed to teach how a DC motor works. For plans to build a working St. Louis motor, go to the web site above, and click on Web Links to find out where to go next.



The St. Louis motor

TOPIC 6 Review

1. Who first observed the connection between magnetism and electricity? What did this person observe that led to the discovery?
2. Describe at least *two* ways in which an electromagnet can be made stronger.
3. What is the difference between AC and DC? How is each type of current usually produced? Why do we use AC in our homes?
4. In what ways are electric generators and motors similar? In what ways are they different?
5. What is the function of brushes and a split-ring commutator? Where are these items used?
6. Describe what parts the following components play in the operation of a DC motor: commutator, brushes, permanent magnets, and armature.

TOPIC 7 Electricity in the Home

Do you know how power reaches your home from an electricity-generating power station? How is the power distributed through your home? How do you pay for the electricity you use?

Transmission of Electricity through the Power Grid

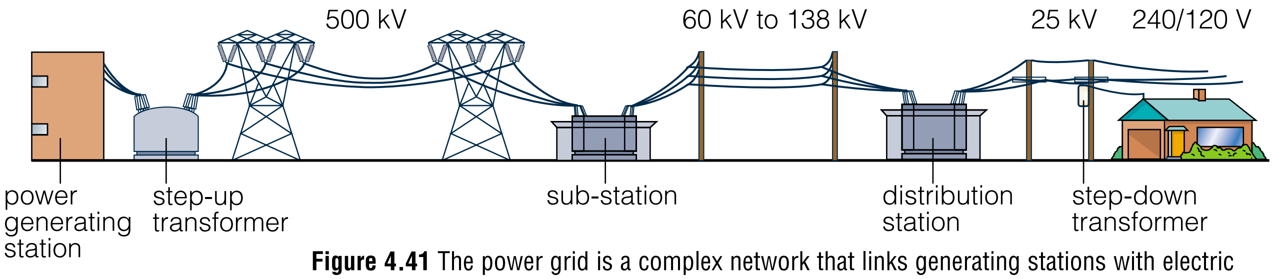


Figure 4.41 The power grid is a complex network that links generating stations with electric energy users such as homes and factories.

Alternating current for use in homes and industry is produced by large electric generators in power stations. **Transformers** are used to "step up" the voltage for efficient transmission over long distances. At the destination, other transformers "step down" the voltage to the 240/120 V used in homes and factories. There is probably a step-down transformer near your home, perched on a power pole, or in a back alley.

Find Out ACTIVITY

Build a Transformer

A transformer is composed of two coils of wire wrapped around an iron core. In this activity, you will build a simple transformer and investigate its operation.

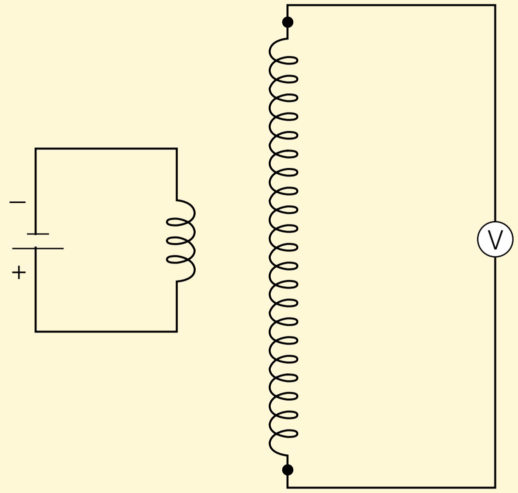
Materials

iron nail, bolt, or rod at least 10 cm long
2 lengths of magnet wire (22 or 24 AWG) about 1.5 m long
1 D-cell in holder
sensitive analog voltmeter
sandpaper (a small square)

Safety Precautions

Procedure Performing and Recording

1. Coil half of one length of wire neatly and tightly around the nail near one end. Leave extra wire free at each end of the coil.
2. Coil most of the other wire near the other end of the nail (leave about 10 cm of wire free at each end). Do not let this coil touch the other one.
3. Sand off the insulating coating from all exposed wire ends.
4. Attach the ends of the first wire coil to the voltmeter.
5. Touch the ends of the second wire coil to the terminals of the D-cell. Observe the voltmeter reading as you connect and disconnect the cell.



What Did You find Out? **Analyzing and Interpreting**

1. What happened to the reading on the voltmeter as you connected and disconnected your transformer to the cell? What happened during the interval that the cell was connected?
2. Was your transformer connected as a step-up transformer or as a step-down transformer? How do you know?
3. Based on your observations, explain why transformers are not used with direct current.

From the Grid into Your Home

Distribution lines connect your home to the power grid through a step-down transformer and a power meter (Figure 4.42). The meter is usually mounted on the outside wall of buildings where the distribution lines enter. It records the total electric energy supplied to electric devices that are operating in the house.

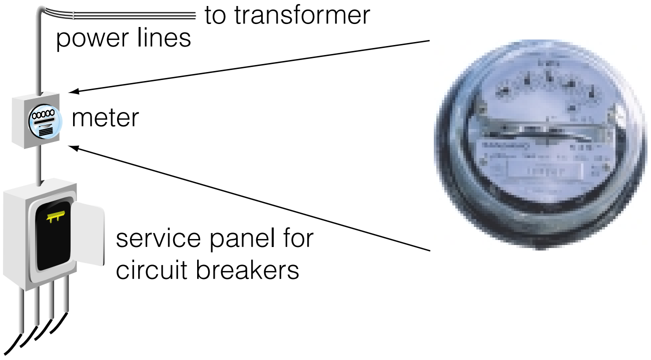


Figure 4.42 The amount of electric energy supplied to your home is measured by a meter and distributed by a service panel.

After being metered, electricity then goes to a service panel. At the top of the panel, wires from the meter are connected to the main **circuit breaker**. The main breaker acts as a switch and safety device that can cut off all power coming into the home. If current exceeds a safe level, a bimetallic strip in the breaker heats up, bends, and opens the circuit. Current stops flowing until the breaker cools and you reset it.

Older homes often have a **fuse** box instead of a breaker panel. A fuse contains a metallic conductor that melts when excessive current heats it up. This opens the circuit until the fuse is replaced. Fuses are rarely used in modern buildings, but they are common in electric stoves and automobile electrical systems.

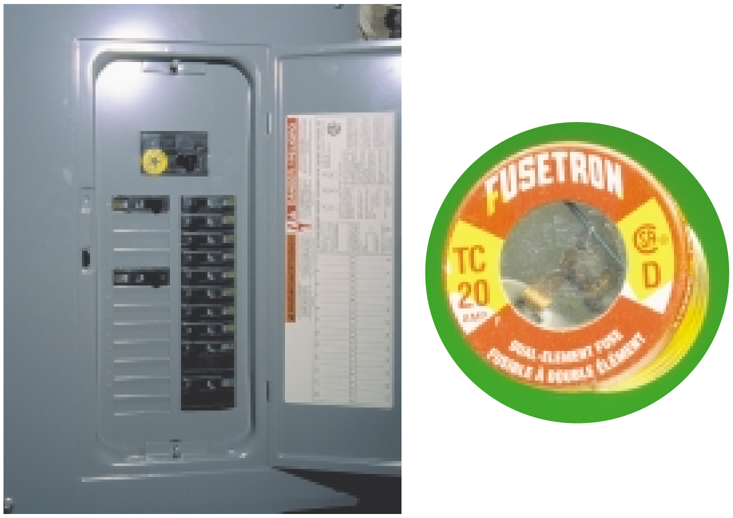


Figure 4.43 Circuit breakers (left) and fuses (right) “blow” if current becomes excessive. This fuse stops current greater than 20 A, preventing overheated wires and possible fires.

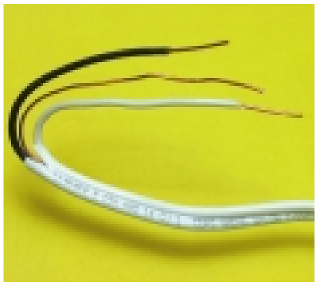


Figure 4.44 Fourteen gauge electric cable, commonly used for home wiring.
Black = hot,
white = neutral,
bare copper (sometimes green) = ground.

The lower part of a service panel contains additional circuit breakers or fuses for each **branch circuit** in your home. Each branch circuit supplies power to one or more wall plugs or lights connected in parallel by cables in the house walls. As additional loads are plugged into a branch circuit, the current flowing through the connecting cables increases. The small resistance of the cable wires causes them to heat up when enough current flows. Before the wires become hot enough to start a fire, the branch breaker or fuse cuts off current to all loads in that circuit. Because the branch circuits are connected in parallel, however, appliances or devices plugged into other branches will continue to operate.

The breakers, plugs, lights, and switches in each branch circuit are connected by electric cables that contain three wires. There are two “live” wires — a white insulated wire (usually called the **neutral wire**) and a black insulated wire (usually called the **hot wire**). The third wire, the **ground wire**, is either bare copper or covered with green insulation. In North American homes, there is a potential difference of 120V across the black and white wires, in curcuits for lamps and ordinary appliances (220-240V for kitchen ranges). The ground wire reduces shock hazards by safely channelling back into the ground any current that has “leaked” onto metal components in the electric circuit.

Home Wiring

To install or modify wiring in your home, it is usually necessary to get a permit from your city, town or municipal office. Licensed electricians who do the wiring must follow strict regulations and practise extreme caution when changing or repairing circuit components. After major wiring work is complete, an electrical inspector may need to certify that the job meets a set of standards called the **electrical code**.

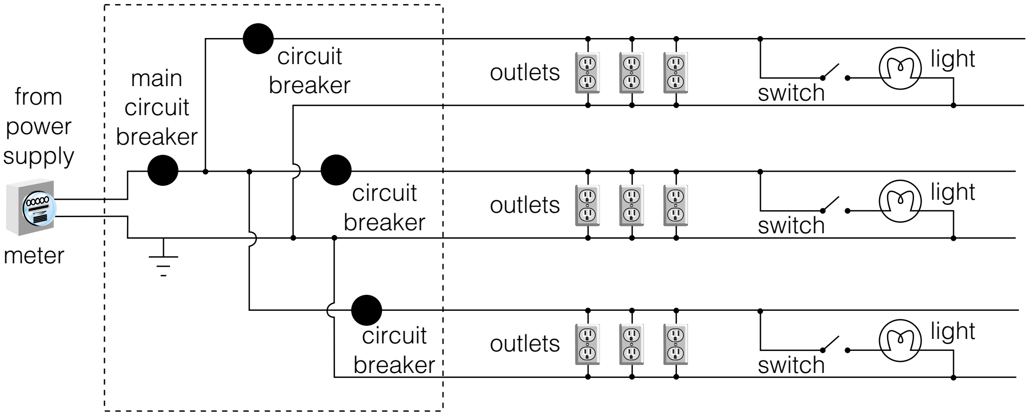


Figure 4.45 A single service panel supplies and controls current to dozens of branch circuits in a typical house. Only three branch circuits are shown in this wiring diagram.

Find Out ACTIVITY

Circuit Training in Your Room

To plan the wiring in a new home, electricians and, in some cases, electrical engineers draw circuit diagrams that show where the different electric fixtures will be placed and how they will be connected. In this activity, you will have the opportunity to draw a circuit diagram of your room.

Materials

pencil
ruler
graph paper

Procedure

1. Measure your bedroom and draw an accurate scale floor plan that includes doors, windows, wall switches, electric outlets, and permanent light fixtures.

2. Find out which electric components in your room are connected together. The light switch, for example, probably does not control the wall outlets. On your plan, draw a possible wiring diagram for your room.

3. Draw a circuit diagram for your room using standard symbols for lights and switches, and a circle with an "X" inside for wall outlets.

What Did You Find Out? ✴ Analyzing and Interpreting

1. Where in your circuit compared to the receptacles and the lights would the light switch be located? Explain the reason you chose this location.

2. Describe at least three things you must consider when wiring a bedroom.

3. How is the circuit diagram for your room similar to the diagrams you have previously drawn of simple circuits? How is it different? (Give at least two answers for each question.)

Extension

4. Imagine that you wanted to add an additional receptacle to your room, controlled by the existing light switch. On your circuit diagram, show the additional electric components in a different colour. Explain the reason for each placement.

Career CONNECT

Electricity runs in Craig Terakita's family. For about 25 years, Craig has worked in his family's electrical business. Every day, he wires residences so they will have safe and efficient heating, lighting, and power. He can do it all — from applying for wiring permits and preparing cost and material estimates, to stringing electric cable through walls, installing plugs and switches, and hanging light fixtures. Craig often works eight to ten hours each day, but he enjoys being on the job with other tradespeople, even when projects require working on weekends.

"To do this job, you need a strong math background," Craig says. He spent four years in postsecondary education, taking classes and then apprenticing for between eight and 12 weeks per year. Now, as a master electrician, Craig's training and experience make him very aware of the potential danger of electricity. He treats it with great respect.

Does a career as an electrician interest you? You can learn about requirements and training opportunities from your school guidance counsellor, the library, or the Internet.

Digital Devices

Have you ever peeked at the circuit board inside a calculator or computer? The four basic circuit elements are present there, although they may take unfamiliar forms. Conductors, for example, may be thin traces of copper instead of wires. Some loads, such as resistors and lamps, resemble the components you have been using. What you do not see are the thousands or millions of tiny electronic switches that form the heart of **digital** electronic technology — machines that process numerically coded information.

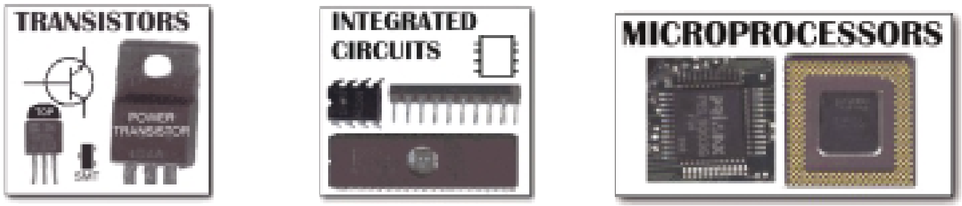


Figure 4.46 Modern digital electronic devices are based on transistors, integrated circuits with several transistors in the same case, and microprocessors (chips), which contain millions of transistors.

Switches have only two states: on or off. These states can be used to represent numbers and letters using a **binary code**, a sequence of “on” and “off” signals. In addition, logic circuits containing many switches can process binary information. For example, you can build a logic circuit that will compare two numbers, add them, or find their difference.

The electronic switches in modern digital devices are **transistors**, solid-state components that can be turned on and off by electric signals. In turn, transistors can control other signals. Every digital device you use, from your calculator to your CD player, is designed around components that contain enormous numbers of transistors (Figure 4.46).

DidYouKnow?

Most digital devices operate on direct current. The power cube transformers (adapters) that allow personal electronic equipment to operate from household power convert 110 V AC to low-voltage DC that replaces energy from batteries.

Cool Tools

Devices called “surge suppressors” (or “surge protectors”) are often used to protect expensive electronic equipment, such as computers, televisions, stereos, home theatre systems, and fax machines. Surges of electric charge, which are momentary increases in the energy (voltage) of the supply to tens of thousands of volts, can occur through household electric wiring and also through telephone lines and coaxial cable. Surges can be caused by lightning, by turning on or off large appliances, or by a local power company transferring large amounts of electricity into or out of the power grid.The suppressor absorbs some of the electric surge and then diverts the rest to the ground.

Measuring Electric Power

In physics, **power** is defined as energy per unit time. Electric power describes the amount of electric energy that is converted into other forms of energy (heat, light, sound, or motion) every second. As well, electric power can also describe the amount of electric energy that is transferred from one place to another in a certain amount of time. The symbol for power is P. The mathematical equation that defines power is:

$$\text{Power (in watts)} = \frac{\text{Energy (in joules)}}{\text{Time (in seconds)}}$$

$$P = \frac{E}{t}$$

The units of power are joules per second. One joule per second is also called one watt (W) in honour of James Watt (1736–1819). A 100 W light bulb, for example, converts 100 W of electric energy into light and heat every second. A kilowatt (kW) is 1000 watts.

Word CONNECT

One watt is a relatively small amount of electric power. Electric power production and transmission involves much more power, which is expressed as:

kilowatts (kW) = 1 000 W

megawatts (MW) = 1 000 000 W

gigawatts (GW) = 1 000 000 000 W

Electric power is not usually calculated directly by measuring energy and time. It is much more common to measure the voltage and current in a circuit and use these quantities to calculate power.

$$\text{Power (in watts)} = \text{Current (in amps)} \times \text{Voltage (in volts)}$$

$$P = IV$$

This equation can be manipulated to determine the current or the voltage of the circuit.

$$\text{Current} = \frac{\text{Power}}{\text{Voltage}} \qquad I = \frac{P}{V}$$

$$\text{Voltage} = \frac{\text{Power}}{\text{Current}} \qquad V = \frac{P}{I}$$

Model Problem

A current of 13.6 A passes through an electric baseboard heater when it is connected to a 110 V wall outlet. What is the power of the heater?

Given

$I = 13.6\text{ A}$
$V = 110\text{ V}$

Required

Power, P, in watts (W)

Analysis

Since you know the potential difference and the current, use the equation $P = IV$ to calculate the power.

Solution

$$\begin{aligned} P &= IV \\ &= 13.6\text{ A} \times 110\text{ V} \\ &= 1496\text{ W} \\ &= 1.50 \times 10^3\text{ W} \end{aligned}$$

Paraphrase

13.6 A of 110 V current passing through an electric heater is a power of 1.50×10^3 W.

Pause& Reflect

Review the units and symbols for the new quantities that you have learned. Add the unit and symbol for power to the table in your Science Log. Include the relationships between watts, joules, and seconds.

Practice Problems

1. What is the power (in watts and kilowatts) of a hair dryer that requires 10 A of current to operate on a 120 V circuit?
2. The maximum current that a 68.5 cm television can withstand is 2 A. If the television is connected to a 120 V circuit, how much power is the television using?
3. A 900 W microwave oven requires 7.5 A of current to run. What is the voltage of the circuit to which the microwave is connected?
4. A flashlight using two 1.5 V D-cells contains a bulb that can withstand up to 0.5 A of current. What would be the maximum power of the bulb?

DidYouKnow?

James Watt (1736–1819), a Scottish engineer, is known for improving the efficiency of the steam engine. To describe the power of steam engines and other devices, he compared them to horses. Watt defined the power of a strong horse as one horsepower. One horsepower equals 746 W. What is the power in watts of a small car with a 100 hp engine?

Paying for Electric Energy

Producing and distributing electric energy is expensive. Power companies pass their costs on to customers according to the amount of energy supplied to each user. To determine this amount, a power company employee records the reading on every customer's electricity meter at regular intervals.

You can read an electric meter yourself. On the meter, each dial represents one digit in a five-digit number. When a dial pointer is between numbers, the lower number is recorded (Figure 4.47). For convenience, most power companies measure electric energy in a customary (non-SI) unit — the kilowatt hour (kWh). One kilowatt hour is the total energy supplied to a 1000 W load during 1 h of operation. For example, a small hair dryer might be rated at 1000 W (1 kW). If it ran for 1 h, the dryer would have transformed 1 kWh of electric energy into thermal energy.

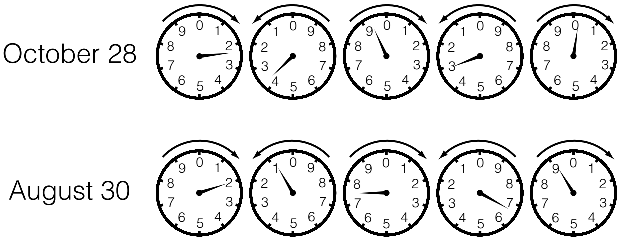


Figure 4.47 The bottom row of meter dials show an August 30 reading of 20 769 units. The top row of dials show an October 28 reading of 23 930 units. The power company would bill this customer for 3161 units of electric energy.

Model Problem

A family uses 3000 kWh of electric energy in a two-month period. If the energy costs 11.0 cents per kilowatt hour, what is the electric bill for the period?

Given

$E = 3000$ kWh
Unit cost = 11.0 cents per kilowatt hour

Required

Total cost in dollars

Analysis

Convert unit cost from cents to dollars. Then find the total cost by using the following formula.
Total cost (dollars) = Total energy used in kWh × cost in $ per kWh

Solution

Total cost

$$= 3000 \text{ kWh} \times \frac{\$0.11}{\text{kWh}} = \$330.00$$

Paraphrase

The cost of electric energy used in this home over a two-month period was $330.

Practice Problems

1. (a) If a refrigerator requires 700 W of power to function, how many kilowatt hours of power will it require in a 30-day period?

(b) If electricity costs 11 cents per kilowatt hour, how much would the refrigerator cost to operate in that period?

2. A home-owner finds that she has a total of 42 light bulbs (100 W) in use in her home.

(a) If all of the bulbs are on for an average of 5 h per day, how many kilowatt hours of electricity will be consumed in a 30-day period?

(b) At 11 cents per kilowatt hour, how much will operating these lights cost the home-owner during that period?

(c) How much money would the home-owner save if she switched all of the bulbs to energy-saving 52 W light bulbs?

3. Bob has a stereo that operates at 120 V, using 2.5 A of current.

(a) How much power does Bob's stereo need to operate? (Hint: Think back to the previous power-calculation Practice Problems.)

(b) If Bob plays his stereo for an average of 5 h each day, how much electricity will he use in a 30-day period?

DidYouKnow?

The amount of energy a person uses on a low-activity 24 h day is about the same as the energy that a 100 W light bulb uses when it is on for 24 h. People, of course, obtain energy from food.

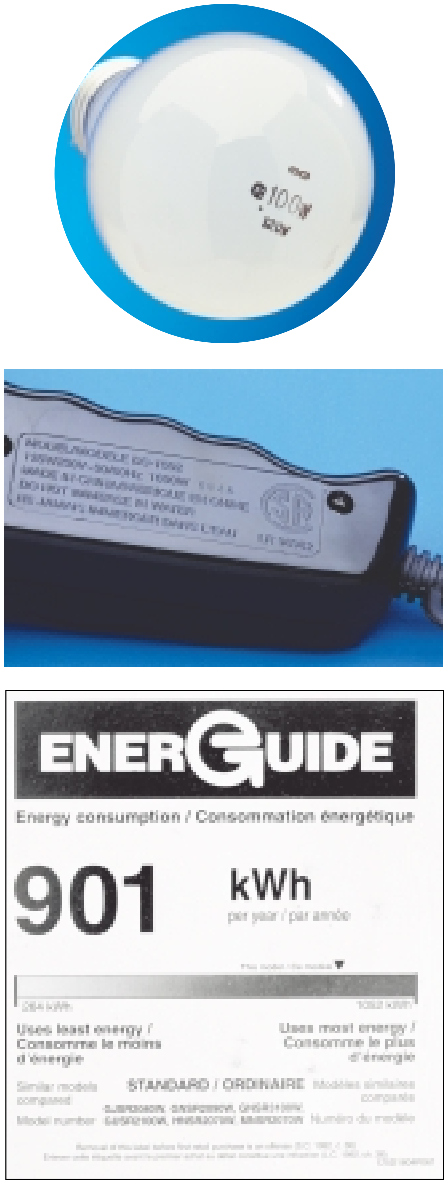

100W
120V
ENERGUIDE
Energy consumption / Consommation énergétique
901
kWh
per year / par année
Uses least energy / Consomme le moins d'énergie
Uses most energy / Consomme le plus d'énergie
STANDARD / ORDINAIRE

Figure 4.48 A power rating or yearly energy use information is marked on most electric devices.

Power Rating

Many electric appliances, such as hair dryers, electric kettles, and even light bulbs, have a power in watts marked on them. This rating tells you how many joules of energy the device uses in every second of operation. (Remember, 1 W is 1 J/s.)

"EnerGuide" labels, such as the one shown in Figure 4.48, help people to make comparisons of energy use when purchasing large home appliances. Stoves, refrigerators, washers, dryers, air conditioners, and similar appliances sold in Canada carry EnerGuide labels. The large number at the top of the label indicates the approximate amount of energy the appliance will use in one year of typical operation. The coloured bar on the label shows how that particular appliance compares with others on the market. The numbers on the bar give the yearly energy use of the most efficient (left end) and least efficient (right end) appliances of similar type. EnerGuide ratings are assigned after appliances are tested according to standard procedures accepted by the Canadian Standards Association (CSA).

Together, all the appliances in your home require a surprisingly large amount of electrical power. Examine Table 4.9 to find some typical examples. In the next investigation, you will determine how your household uses electric energy.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Most major power companies offer electric power-consumption calculation tools on their Internet sites to help you find out where your family's power consumption dollars are going. Many power company sites also offer energy conservation suggestions. To find some that you could begin to use, go to the web site above, and click on Web Links to find out where to go next.

Table 4.9 Power Ratings and Energy Use for Appliances

Appliance	Power P (W)	Average energy used per year (MJ)	Appliance	Power P (W)	Average energy used per year E (MJ)
clothes dryer	4356	3600	CD player	85	500
dishwasher	1200	1300	TV (colour)	200	1600
range and oven	12 200	4200	washing machine	512	400
refrigerator	615	6600	water heater	2475	5000

THINK & LINK

INVESTIGATION 4-I

SKILLCHECK

Initiating and Planning

- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

You've Got the Power!

Think about how electricity is used in your home. Which appliances are costing you the most to operate? Which cost you the least? What would be the easiest way to reduce your household's electricity bill and perhaps help the environment without major changes in your lifestyle?

What To Do

1. Construct a large data table in which to record the information you collect.
2. At home, list all of the major and minor electric appliances or devices that are used in your home.
3. For each device, try to estimate the average number of hours per day (and then per month) that it is used. Ask members of your household for their input or check a power company website for average values.
4. For each device, record any information you can find that is related to the wattage, voltage, or amperage required by the device. Consult the appliance power-consumption reference sheet supplied by your teacher for wattages you cannot determine. If wattages cannot be found for certain devices, attempt to calculate power use by using data for voltage and current and the equation (watts = volts × amps) you learned earlier. The voltage of a standard receptacle is 120 V.
5. Calculate the number of kilowatt hours of electricity consumed by each device in a month. From these values, determine the total monthly electricity consumption by your household.
6. Use the current rate your household is paying for electric power to calculate the monthly power bill. (You can find the current rate per kilowatt hour from a recent electric bill or by contacting the local power company.)

Analyze

1. Which appliances or devices did you find were costing you the most money in terms of electricity consumption? Which cost the least? Explain why you think this was the case. Give at least two explanations for each of the high- and low-cost devices.

2. Suppose that your goal is to reduce your power bill by $25.00 over a 30-day period.

(a) At the rate your household is currently paying for electricity, by how many kilowatt hours of power would you need to reduce your consumption to save $25.00 in a 30-day period? Show your detailed calculations.

(b) Describe in detail what measures you could take to reduce your electricity consumption by the number of kilowatt hours you calculated in question 2 (a).

Electric Devices and Efficiency

If an electric light bulb were perfect, all of the electric energy it took in (input energy) would be converted into light (useful output energy). No real device, however, is a perfectly efficient energy converter. Some input energy is always converted into waste heat.

You can express efficiency as a percentage by using the following mathematical relationship.

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

To find the efficiency of electric devices, it is often necessary to calculate energy inputs or outputs.

To determine the electric energy input of a device, the formula for power $\left(P = \frac{E}{t}\right)$ can be manipulated to solve for energy.

$E = Pt$ or energy (joules) = power (watts) × time (seconds)

Different types of electric lighting provide a good example of differences in efficiency.

Incandescent Bulbs

Electric lighting in most homes is largely provided by incandescent light bulbs, which are only about 5% efficient. About 95% of the input electric energy is converted to waste heat as current passes through a thin metal filament coiled inside the bulb.

Halogen Bulbs

Halogen bulbs are filled with a high-pressure gas containing traces of iodine, which helps prevent their filament from evaporating. This allows the bulbs to operate at very high temperatures, so they convert a greater proportion of their input energy into light. Although halogen bulbs are about 15% efficient, they still waste a significant amount of energy as heat and can be a fire hazard. Halogen bulbs last two to six times longer than incandescent bulbs.

Fluorescent Tubes

A fluorescent tube contains a gas such as mercury vapour. When current passes through the vapour, it emits energy that affects a white material on the inside of the glass, causing it to glow. Fluorescent tubes operate at relatively low temperatures, so they waste very little energy as heat. Most fluorescent tubes are about 20% efficient, and they last ten to 13 times longer than incandescent bulbs. Compact fluorescent bulbs are much more expensive than the regular light bulbs which they can replace. Fluorescent bulbs' long lifetime and low power consumption, however, more than repay this initial cost. By using less electricity, compact fluorescent bulbs also reduce the environmental impact of generating their operating power.

Figure 4.49 Replacing traditional light bulbs with more efficient compact fluorescent bulbs (bottom) can significantly reduce energy requirements and operating costs for electric lights.

Model Problem

A 1000 W electric kettle takes 4.00 min to boil some water. If it takes 1.96×10^5 J (196 000 J) of energy to heat the water, what is the efficiency of the kettle?

Given	**Required**
$P = 1000$ W	Efficiency
$t = 4.00$ min	
Useful energy output $= 1.96 \times 10^5$ J	

Analysis

To find the energy used by the kettle, use the formula $E = Pt$.
To find the efficiency of the kettle use

$$\text{efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} \times 100\%$$

Solution

Convert time into seconds.

$$t = 4.00 \text{ min} \times \frac{60 \text{ s}}{\text{min}} = 240 \text{ s}$$

Find the electric energy input to the kettle.

$$\begin{aligned} E &= Pt \\ &= 1000 \text{ W} \times 240 \text{ s} \\ &= 240\,000 \text{ J} \\ &= 2.40 \times 10^5 \text{ J} \end{aligned}$$

Find the percent efficiency.

$$\text{efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} \times 100\%$$

$$\text{efficiency} = \frac{1.96 \times 10^5 \text{ J}}{2.40 \times 10^5 \text{ J}} \times 100\% = 81.7\%$$

Paraphrase

The kettle is about 81.7% efficient.

Math CONNECT

Look again at the mathematical relationship that defines efficiency. High efficiency (near 100%) means the useful output energy is almost the same as the input energy. Very little energy is transformed into waste heat. *High* efficiency means *low waste*. What would it mean for a device to have efficiency greater than 100%? Do you think this is possible?

Practice Problems

1. Find the efficiency of a 23 W fluorescent tube that is used 4.0 h per day and in that time produces 6.624×10^4 J of useful light energy.
2. A 100 W incandescent bulb also produces about 6.624×10^4 J over a 4.0 h period. What is the efficiency of this bulb?
3. Based on your answers to questions 1 and 2, how much money would you save in a 30-day month if you replaced 25 of the 100 W incandescent bulbs with 23 W fluorescent bulbs? Assume that the bulbs operate 4 h daily, and that electricity costs 10¢ per kilowatt hour.

Home Electric Safety

It does not take a very large electric current to do serious damage to a person. Electricity-related injuries often occur when a person's body accidentally becomes a conducting pathway by which electricity can reach the ground. Current flowing through the body — an electric shock — can cause pain, muscle spasms, and even death. In addition to injuring people directly, electrical faults are a common cause of household fires. Fortunately, simple safety measures can help to prevent you from being harmed by electricity.

- Do not overload an outlet or a circuit by plugging in too many electric devices. Overloading can cause the wiring to heat up and could lead to a fire.
- Never work on or clean appliances that are still plugged in. You might touch a "hot" wire and become a path to the ground.
- Replace frayed or worn out electric cords. If a person touches the exposed wires, electric current may flow through the person's body rather than through the load. If the bare wires touch directly (a **short circuit**), a high current flows between them, causing sparks and often starting a fire.

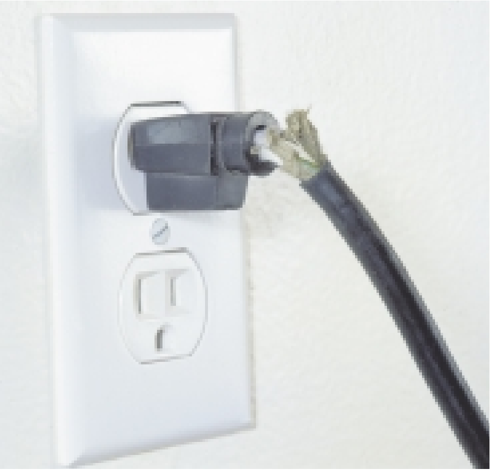


Figure 4.50 Frayed electrical cords are a serious shock and fire hazard.

- Use receptacle covers on easily accessible outlets to prevent small children from sticking objects into receptacles, causing short circuits or shocks.
- Never use appliances close to a sink or bathtub with water in it or when your hands are wet.

Cool Tools

Emergency medical personnel sometimes use an electric *defibrillator* to apply a controlled electric shock to an accident victim's heart muscle. If the heart has stopped, the shock can cause it to contract and begin beating again. If the heart muscle is contracting in uncontrolled spasms, its normal rhythm can be restored by the shock, which is applied through a paddle-shaped electrode. Some portable defibrillators even "speak" computer-generated instructions to guide inexperienced users.

DidYouKnow?

You have probably seen outlets with reset buttons, such as the one in the photograph. These buttons indicate that the outlet is connected to a ground fault circuit interrupter (GFCI). These devices are required in areas such as bathrooms and outdoor locations where water and electricity create a hazard.

A GFCI monitors current flowing into and out of a load. If any electricity is diverted out of the circuit wires, the GFCI immediately cuts off the current. If the problem is caused by electricity leaking from the load and through a person's body to the ground, opening the circuit could prevent a potentially fatal electric shock.

Electric Safety Outdoors

Electric hazards exist outdoors as well as inside your home. Power poles, transformers, substations, and overhead wires can all be dangerous. To protect yourself from a possibly fatal electric shock, you should follow a few simple rules.

- Never allow your body or something you are holding to come into contact with live electric wires. Touching a kite string, ladder, branch, or TV antenna that is in contact with power wires can make you a pathway to the ground, causing electricity to flow through your body.
- Never use ungrounded or frayed two-prong electric cords outdoors.
- Do not operate electric equipment outdoors when it is raining.
- Before digging deeply in your yard, make sure that there are no underground utility cables. A shovel can cut through buried communications wires and disrupt telephone or cable television service. Heavy equipment or power posthole diggers can pierce the insulation of underground power cables, creating a risk of serious shock for the equipment operator as well as causing a power outage. Utility companies will send an employee to your property on request, to locate and mark underground wires and pipes without charge.

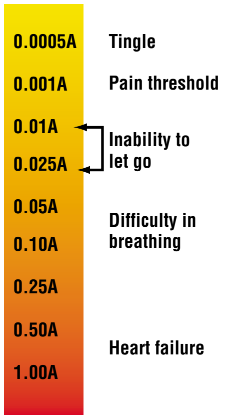
Off the Wall

Effects of Electric Current

The scale shows how the effect of electric current on the human body depends on the amount of current that flows into the body. The average circuit in a home carries a maximum current of 15 A. Extreme caution must be used when dealing with electricity because of the danger that this level of current poses.

Effects of Electric Current

The scale below shows how the effect of electric current on the human body depends on the amount of current that flows into the body.



TOPIC 7 Review

1. Describe the purpose and location in the power grid of:
   (a) step-up transformers
   (b) step-down transformers
2. Calculate the cost of using a 300 W television for:
   (a) 6 hours when electricity costs \$0.11 per kWh.
   (b) 300 hours when electricity costs \$0.16 per kWh.
3. Describe the difference between a circuit breaker and a fuse.
4. Describe three ways in which electric energy could be conserved with respect to home lighting.

TOPIC 8

Electricity Production and the Environment

Canadians use about 2 000 000 000 000 000 000 J (2×10^{18} J) of electrical energy every year. Powering the generators that provide this electricity is an enormous task that has significant environmental effects.

Electric Energy from Burning Fuels

Fuel oil, natural gas, and coal, are burned in large **thermo-electric**—generating plants to produce about one quarter of our country's electricity. These fossil fuel resources are being consumed faster than they are produced in nature, so they are considered **non-renewable resources**.

Biomass, solid material from living things, can also be burned to power thermo-electric generators. Trees, agricultural crops and crop wastes, aquatic plants, wood, animal wastes, and municipal wastes: all these substances can be used as fuels, or turned into fuels and used to generate electricity. Biomass is considered a **renewable** energy source because it can be continually replenished.

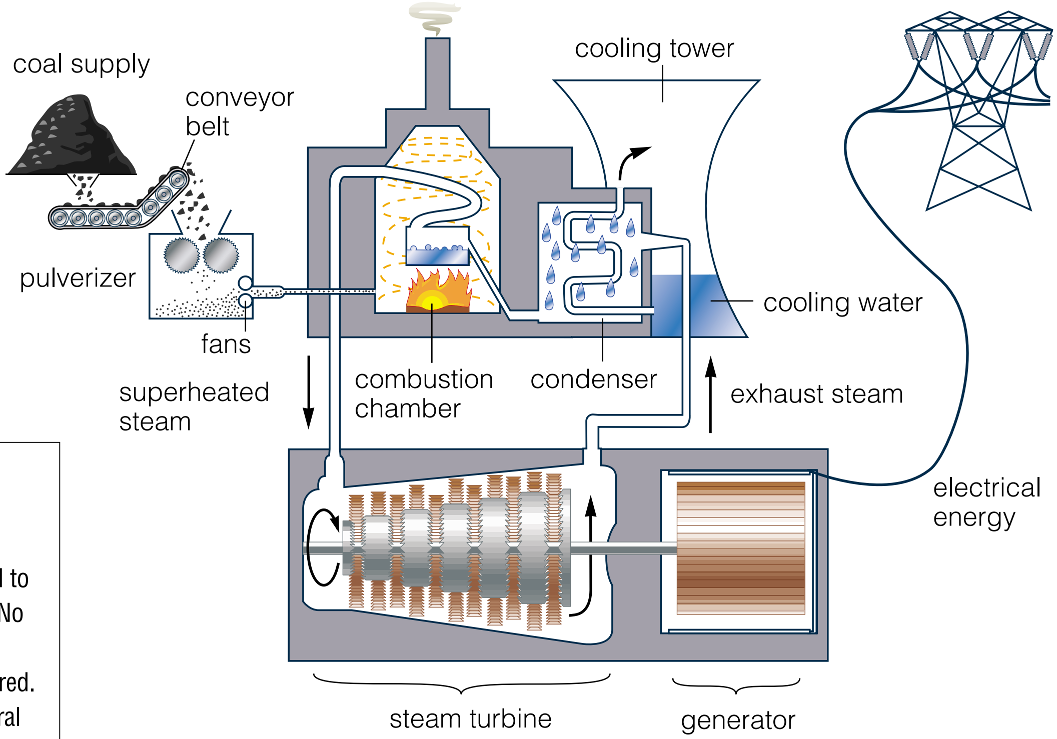


Figure 4.51 Heat from burning coal converts water into steam. The high-pressure steam flows through pipes into a turbine. The spinning turbine turns a generator that produces electric energy. Steam leaves the turbine cooled, condensed, and recycled through the turbine.

Cool Tools

Turbogenerators use exhaust gases from burning fossil fuels to spin a turbine coupled to an electric generator. No steam, condenser, or cooling tower is required. In Alberta, some natural gas production facilities generate electricity with turbogenerators fueled by *flare gas*, a waste product from the facility.

Find Out **ACTIVITY**

Seek the Source

How does electrical production in Alberta compare to other parts of our country? In this activity, you will contrast the most common sources of electric energy in Canada.

Procedure

1. Use the map below and draw *one* bar graph that shows each of the following variables for regions with total production of more than 1000 GW•h. Shade or colour code the four graph bars for each region and include a legend (key) to the code.

- total electricity production
- electricity from *thermo-electric* sources
- electricity from *hydro-electric* sources
- electricity from *nuclear* sources

Computer CONNECT

Use a computerized spreadsheet/graphing program to draw the bar graph.

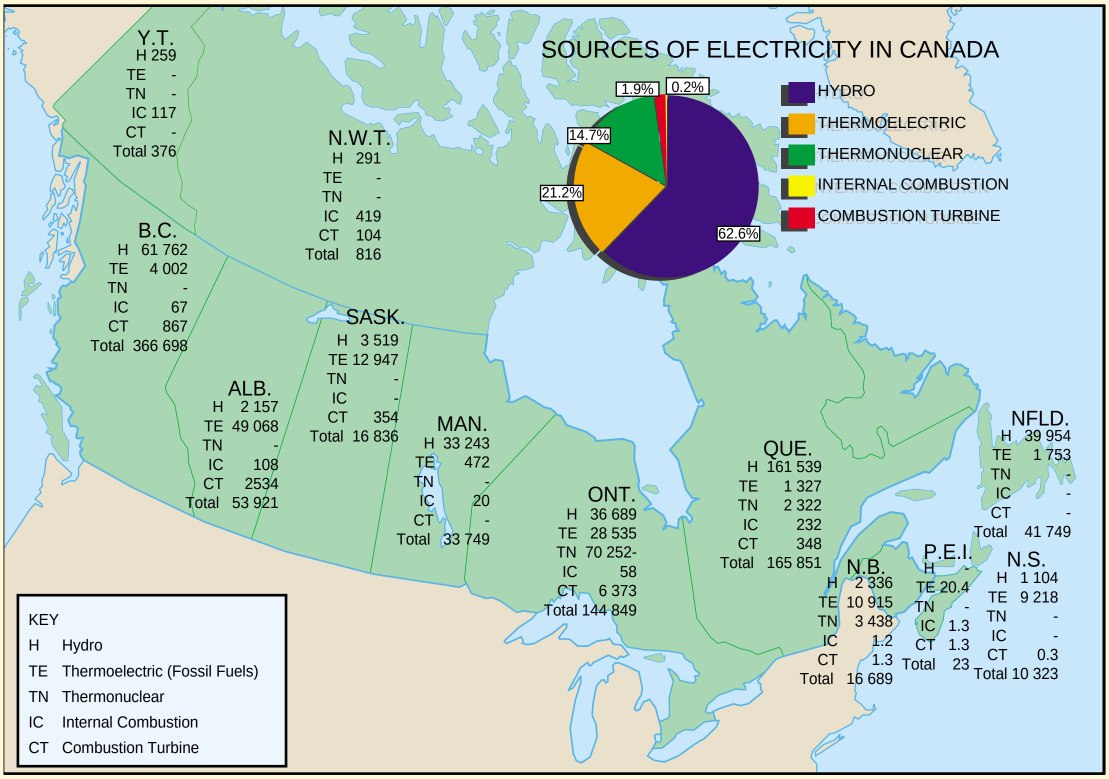
What Did You Find Out?

Analyzing and Interpreting

1. How does total electrical energy production in Alberta compare to that in other provinces? What percentage of Canada's electricity is produced in Alberta?
2. Which source of energy supplies most of Alberta's electricity? How does the electricity production in other provinces from this source compare to that of Alberta?
3. Rank the sources of electricity in Canada from highest to lowest.

Extension

4. Explain why Alberta, B.C., and Ontario produce most of their electricity in different ways.
5. Identify sources of electrical production other than the five mentioned on the map. Explain why each method is not more widespread.



Recent annual values for the amount of electric energy generated in each province are given in GW•h (gigawatt hours). A GW•h is a huge amount of energy: 3.6 × 10^{12} J. (source: Statistics Canada)

INQUIRY

INVESTIGATION 4-J

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- ✸ Analyzing and Interpreting
- ✸ Communication and Teamwork

Efficiency of Electric Lighting from Coal

In every step in the process of mining coal, generating electricity, transmitting it to your home, and lighting a lamp, some energy is used or escapes in the form of thermal energy in the process. In this investigation you will examine the efficiency of operating electric lights with power produced by coal-burning generators.

Question

What percent of the energy originally stored in the coal is actually converted into the electricity used in a lightbulb?

Hypothesis

Examine the information about electricity production that is given below. With your classmates, discuss how to use the figures given to estimate an answer to the question. Calculate an estimate and explain how you arrived at it.

Summary of steps in converting energy stored in coal to electric energy, and to then light in a lamp.

1. *Mining the coal*: Mining coal uses relatively little energy compared with the energy stored in the coal that is produced. About 1% of a typical mine's coal production would supply enough energy to operate the mine. The remaining 99% of the mine's energy output is available for other uses.
2. *Transportation of coal*: Moving coal from the mine to the power plant uses some energy to power the train. The efficiency of transporting coal is about 97%.
3. *Generation of electricity*: Thermo-electric generating plants are not very efficient. Most of the energy from the coal escapes from the stacks or from coolant water as heat. Only about 33% of the energy from the coal that is burned is converted into electricity.
4. *Transmission of electricity*: When electric energy travels through power lines, some of the energy goes into heating the conductors. Electric power transmission is about 85% efficient.
5. *Conversion to light*: Incandescent light bulbs are very inefficient. Most of the electric energy is converted to heat. At best, an incandescent light bulb will be about 15% efficient.

In this investigation, you will start with an amount of coal that has 1 million joules (1 000 000 J or 1.0×10^6 J) of stored energy. You will determine the amount of useful energy that remains after each step in the process. Then you will determine the overall efficiency of the process.

Procedure

1. Make a table with the headings shown below. Allow enough rows for all the steps listed in the summary. Give your table a title.

Step	Energy at beginning of step (J)	Efficiency of step (%)	Energy at end of step (J)	Overall efficiency (%)
mining	1 000 000			

2. In the first column, write the names of the steps in the process of converting the energy stored in coal into electric energy.
3. In the second column, write the percent efficiency of each step.
4. Determine the amount of stored energy that remains after the process described in each step. You can determine this value by using the following formula.

Stored energy remaining =

$$\text{Energy remaining in previous step} \times \left(\frac{\text{efficiency}}{100\%}\right)$$

For example, the stored energy remaining after the first step is

$$\text{Stored energy remaining} = 1\ 000\ 000\ \text{J} \times \left(\frac{99}{100}\right)$$

$$= 990\ 000\ \text{J}$$

Write the answer in the third column. Then 990 000 J will be the "energy remaining" in the previous step when you do the calculations for the second step. Complete all the calculations for "Stored energy remaining."

5. In the third column, compare the remaining energy to the original energy of the coal. You can calculate this value with the following formula.

Overall efficiency =

$$\frac{\text{Stored energy remaining} \times 100\%}{1\ 000\ 000\ \text{J}}$$

Write your results in the last column.

Analyze

1. Which step or steps in the conversion process is most efficient? Which step is least efficient?
2. What is the overall efficiency of converting the energy stored in coal to the energy of light from a light bulb?

Conclude and Apply

3. Carefully examine each step in the conversion process. Using your past studies as background, describe a way in which the efficiency of each step could be improved.

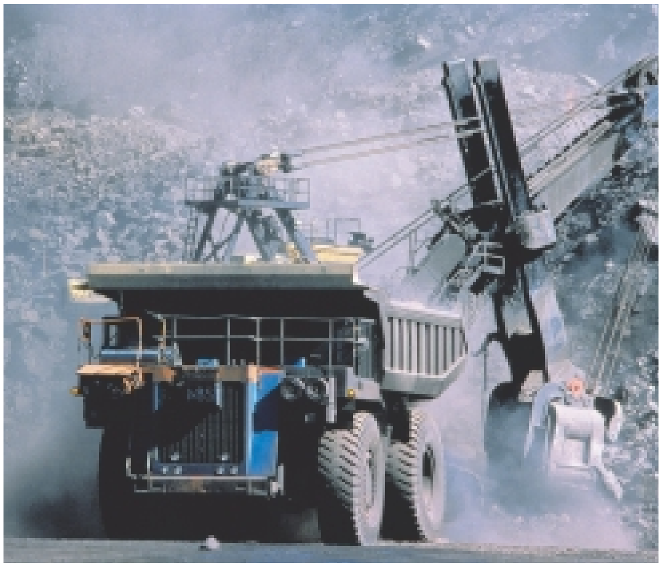


Figure 4.52 Open-pit mines affect land, water, and wildlife so much that projects such as the Cheviot Mine near Jasper have been abandoned after protests by environmentalists.

Fossil Fuels Affect Land and Air

Coal is the most common fuel for thermo-electric power plants in Alberta. Known reserves in this province are huge, enough to provide for as much as 800 years of domestic consumption. Production and use of coal, however, have serious environmental side effects. **Open pit mining** of surface deposits disturbs soil and vegetation (see Figure 4.52). Underground mines produce waste materials called "tailings," which accumulate near the mine. Water used in the mining process or seeping through the tailings becomes acidified and contaminated.

When fossil fuels, including coal, are burned to generate electric energy, contaminants such as visible particles and invisible gases escape from the smokestacks. Electrostatic precipitators can remove most of the solid particles, but they cannot remove contaminating gases, such as sulfur dioxide (SO_2).

Sulfur dioxide is one of the causes of acid rain, which harms plant and animal life. Antipollution systems called **scrubbers** can remove sulfur dioxide. Scrubbers spray a water solution through the waste gases. Most, but not all, of the SO_2 and other pollutants react with chemicals in the water and are removed.

Even if there were no contaminants such as SO_2, complete burning of pure coal or natural gas would still produce carbon dioxide gas (CO_2). Carbon dioxide is a natural part of the atmosphere. Every time you exhale, you breathe out some carbon dioxide. However, carbon dioxide is a **greenhouse gas**, which means that it helps delay the escape of heat from Earth's atmosphere. If too much carbon dioxide, methane, and other greenhouse gases accumulate in the atmosphere, they absorb more heat from the surface of Earth. This could lead to a rise in the average temperatures on Earth — global warming.

The increased concern for the environment has led to more power-generating plants that burn natural gas rather than coal. Natural gas burns much cleaner than coal, producing less SO_2. As electricity demand increases, this fuel, although somewhat more expensive, is an attractive alternative.

DidYouKnow?

Wastes decomposing in landfills produce "landfill gas," which can be used as a fuel for thermo-electric plants. This process is used on a small scale in Edmonton's Clover Bar landfill. Landfill gas is largely methane, the same chemical as natural gas.

Electric Energy from Flowing Rivers

Hydro-electric plants, use water pressure to generate electric energy. Large dams cause the water level to rise high above the power plant, which is often located inside the dam. In previous science courses, you learned that as the water depth increases, the pressure at the bottom becomes very large. Figure 4.53 shows how water flowing under great pressure is used to produce electricity.

A channel, called a penstock, directs the water from the bottom of the reservoir to a turbine. The high pressure of the rapidly flowing water turns enormous turbines, which then turn electric generators. The energy of the water stored in the reservoir is converted into electric energy. High voltage power lines carry the resulting electricity over many kilometres from the hydro-electric plant to cities, towns, and farms.

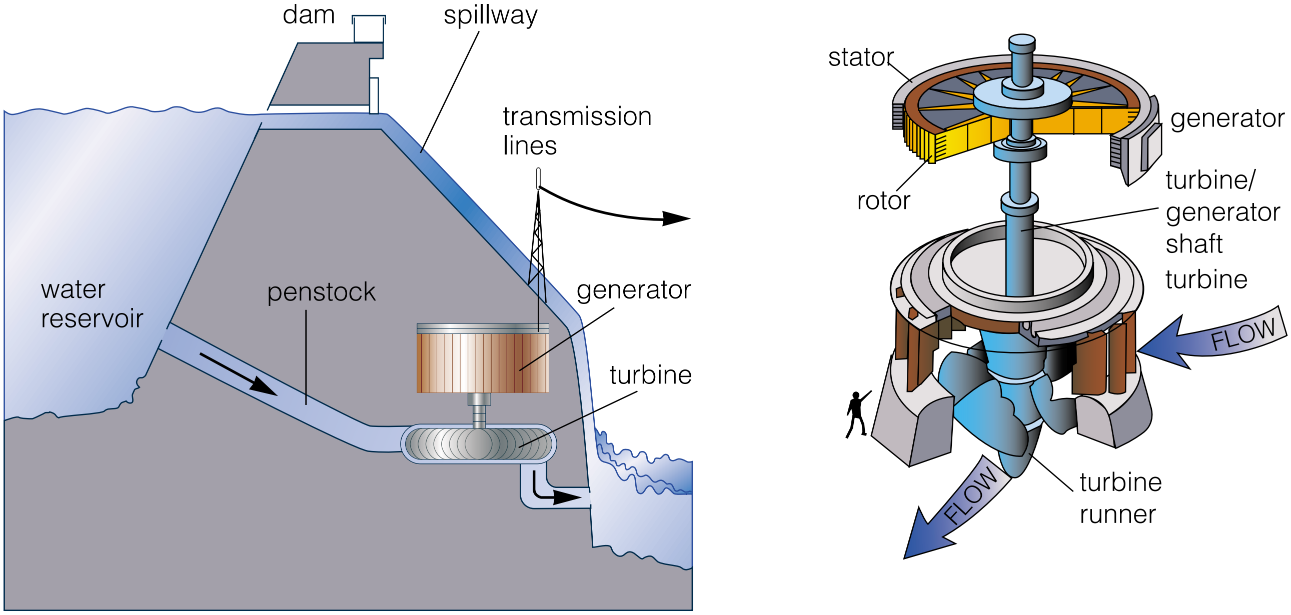


Figure 4.53 Energy is stored in the reservoir due to the tremendous mass of water and its height above the base of the dam. The turbine and generator convert this stored energy into electric energy.

Hydro-electric power plants appear to be a very clean form of electric energy generation. They have no smokestacks and they use no radioactive materials. However, reservoirs, which store water behind the dams, flood many hectares of valuable land. Homes, small villages, and even entire towns may need to be moved, displacing people and industries. When land is flooded, submerged vegetation decays. Micro-organisms responsible for this process use up the oxygen supplies in the water and sometimes decaying matter produces methane gas. These conditions make it impossible for some species of fish to survive. Other forms of life, such as algae, take over and change the ecosystem. No matter where the dam is built, some form of life is threatened.

Energy from Atomic Reactions

Bombarding uranium atoms with tiny particles called neutrons causes the uranium to split into two smaller atoms. In this process, called **nuclear fission**, a tremendous amount of energy is released. Figure 4.54 shows the process of **thermonuclear** electric generation.

The fission reactions produce tremendous amounts of heat, which is carried away from the reactor core by a coolant. Pipes carry the coolant through a tank of water, producing steam. From this point, the process is very similar to a thermo-electric–generating station. The steam turns a turbine connected to a generator that produces electricity. Steam leaving the turbine is cooled, condensed, and recycled. The waste heat is released into the environment.

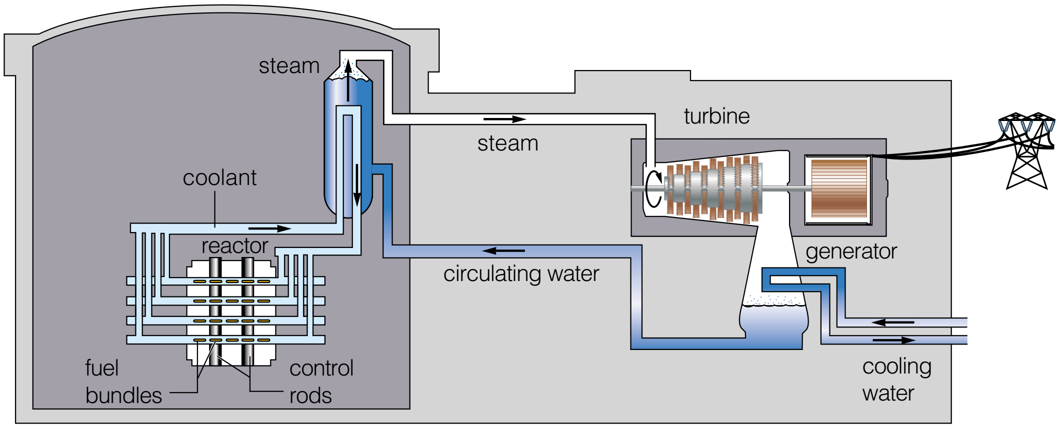


Figure 4.54 This simplified diagram shows how a CANDU (Canadian Deutrium Uranium) reactor produces electricity from nuclear energy. CANDU reactors are designed and built in Canada and have been sold around the world.

Fission reactors do not release soot or gases that cause acid rain, nor do they release greenhouse gases. However, used (spent) reactor fuel is highly radioactive for thousands of years. This means it emits high-energy particles and rays that can damage living tissues. Safe handling, transportation, and storage of these radioactive waste materials are unsolved environmental problems.

The reactors themselves also become slightly radioactive after years of use, so they are difficult and expensive to decommission.

Another type of nuclear reaction, however, does not produce large quantities of radioactive waste. In the Sun and other stars, **nuclear fusion** joins very small atoms to form a larger atom. Huge amounts of energy are released in this process. Scientists have produced controlled fusion reactions experimentally, but only for seconds. Developing technology to create and use continuous controlled fusion as a power source is an extremely difficult and expensive project that will take many decades.

DidYouKnow?

There are no nuclear power stations in western Canada. Many European countries are phasing out their nuclear power stations in favor of more environmentally friendly energy sources.

Heating the Environment

All thermonuclear and thermo-electric–generating plants release thermal energy into the environment. Seventy percent of the thermal energy from nuclear fuel and 43% from coal, oil, and gas leave the plant in the cooling water. **Thermal pollution** occurs when this warm water is returned directly to the lake or river from which it is taken, increasing the water temperature. Even a change of a few degrees can affect the plant and animal life in the water. Organisms adapted to one temperature will not thrive at another, even similar, temperature. Organisms not usually found in the lake or river may begin to replace the original species. To reduce thermal pollution, large generating plants have cooling ponds or towers where waste water can return to the temperature of the surroundings before it is released.

Cogeneration

It makes environmental sense to design electricity-generating stations as **cogeneration systems** that produce electricity and also supply thermal energy, such as hot water or steam, for industrial or commercial heating. Cogeneration power plants are often built near industrial complexes. The plant provides electricity and heat or steam to the industry and may sell excess electricity to the provincial power grid. One example of this type of facility is the Poplar Creek power plant located near Fort McMurray. The power plant provides electricity and heat needed to extract oil from the tar sands and then adds any surplus electricity to the Alberta power grid. Not only do these types of plants reduce the amount of energy wasted, they also reduce the dependence of large industrial power users on the Alberta electricity grid. This reduced demand makes it easier to meet the electricity needs of the rest of the province's consumers.

DidYouKnow?

Distribution of electric power can also cause environmental problems. Power grid transformers built before 1977, for example, often contained insulating chemicals called "polychlorinated biphenyls" or PCBs. PCBs persist, bioconcentrate, and can cause health problems if they are released when aging transformers are replaced. Some people are concerned that high-voltage transmission lines themselves, which produce radiation similar to radio waves, may be linked to health problems in people living nearby.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Three of the largest thermo-electric plants in Alberta are located on Lake Wabamun, which is about 70 km west of Edmonton. Keephills, Sundance, and Wabamun plants produce enough electricity to supply the equivalent of 3.3 million Alberta households. More than 15 million t of coal are burned in these three plants each year, all of which are obtained from surface mines in the area. To learn more about the effects they produce on local ecosystems, go to the web site above, and click on Web Links to find out where to go next.

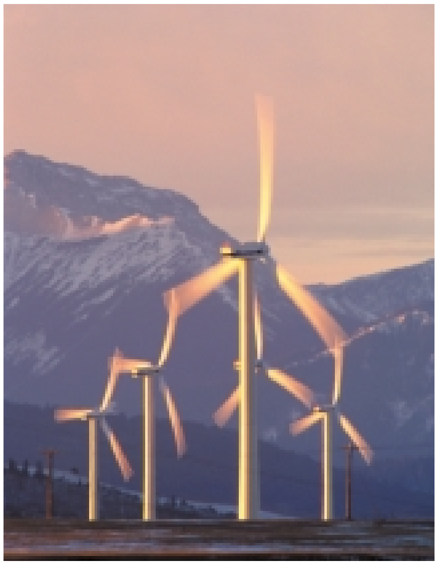


Figure 4.55 Wind turbines similar to these generate electricity which powers C-train public transit equipment in Calgary.

Alternative Energy Sources

In 1998, less than 1% of Canada's electricity was generated from renewable energy sources. As supplies of coal, oil, and natural gas are depleted, however, these fuels are becoming more costly. Energy from the Sun, wind, and tides, which until now has been too expensive or too difficult to harness, is rapidly becoming competitive with conventional energy sources.

Windmills, for example, were used to pump water or generate electricity in rural Alberta for many years. Now, gigantic wind turbines are being used to supply "Green Energy" — electricity generated in an environmentally friendly manner— to the power grid. Large-scale "wind farms" are feasible in regions where the average windspeed exceeds 11 km/h, which is common in southwestern Alberta.

What happens on a windless day? Wind-driven electricity generation must be used together with other electric energy sources or storage devices. For example, wind-generated electricity could charge storage batteries, pump water into a reservoir for generating hydro-electric energy, or split water molecules into hydrogen and oxygen gas for use after as fuel for fuel cells.

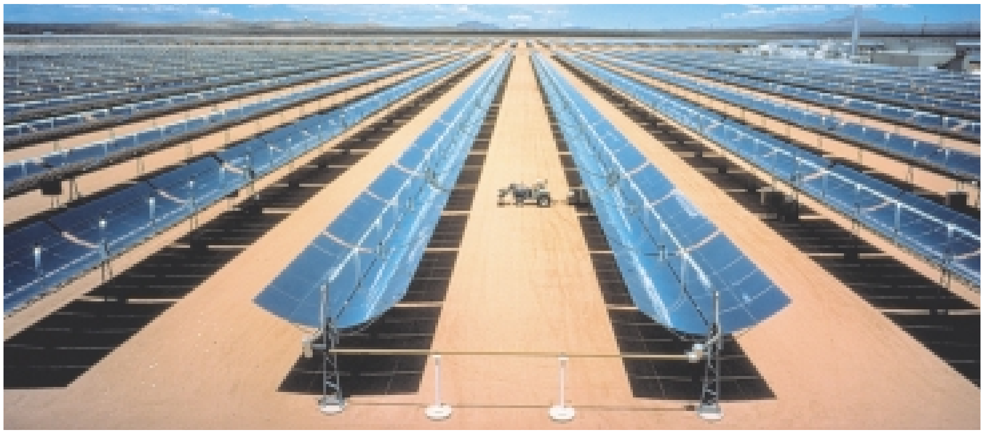


Figure 4.56 Reflective mirrors in the California solar farm are precisely curved to concentrate solar energy on oil-carrying pipes.

Sunlight can also be used to produce electricity on a large scale. "Solar farms" seldom use solar cells because they are expensive, fragile, and convert only about 15% of incoming light energy into electricity. Figure 4.56 shows an alternative method of harnessing solar energy by using it to heat a liquid. The hot liquid flows back to a generating station where it boils water into steam and drives a steam turbine and electric- generator. Solar-energy devices work only when sunlight is reaching the collectors. As a result, solar-powered–generating systems often include storage batteries to supply electricity at night or in cloudy conditions. In sunny conditions, the batteries can be recharged.

Ocean tides are another source of energy that can be used to generate electricity. Twice a day, tides change the water level between 1 m and 17 m, but the enormous energy of this slowly moving water is difficult to utilize. Only a few shorelines around the word have sufficiently high tides and an appropriate shape for trapping tidal waters. Several designs for tidal electricity-generating stations have been tested. As shown in Figure 4.57, the generating station at the Bay of Fundy traps tidal waters that have come in at high tide and uses the energy of the water as it flows out of the bay. Another design allows the station to use the energy of the water continuously, first as it flows into the basin and then again when it flows out of the basin.

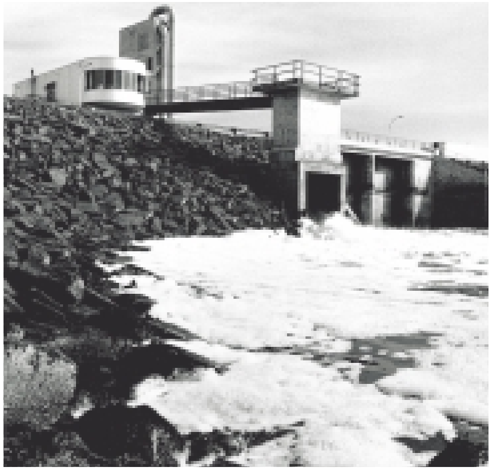
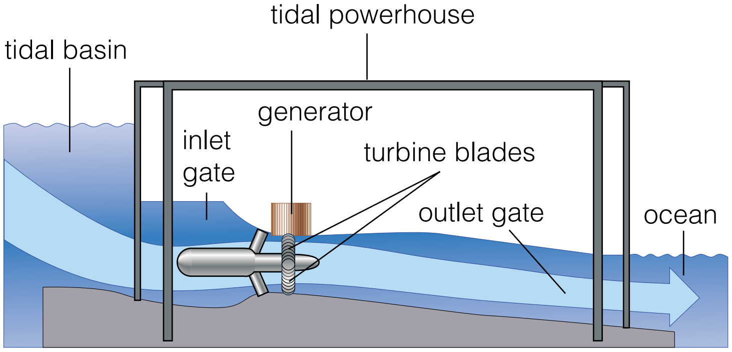


Figure 4.57 The tidal powerhouse is quite similar to a hydro-electric generating station in a dam. As the water that has been trapped in the basin flows out, the water pressure turns turbine blades that turn an electric generator.



The hot inner parts of Earth contain a great deal of thermal energy, called **geothermal energy**. In some places, Earth's crust has cracks or thin spots in it. Ground water flows down from the surface, absorbs thermal energy, and rises again as hot springs and geysers. Steam produced by geothermal activity can be used to rotate turbines and turn electric generators. Because heated groundwater may contain dissolved sulfur compounds, condensed steam from the turbines is often pumped back underground to reduce pollution.

Only certain places on Earth have the proper geological characteristics to use geothermal energy. Iceland is one country that is ideally suited for the operation of geothermal power plants. You may remember that Iceland is located on the boundary of two tectonic plates and is known for its volcanic activity. In Canada, other forms of energy are more available and easily accessible, so use of geothermal energy sources has been limited.

Figure 4.58 Geothermal energy may be used in areas such as Iceland. Why isn't this form of energy the answer for other areas on Earth?

Find Out ACTIVITY

Alternative Methods of Generating Electricity

How can we balance our increasing need for electric energy and our concern about environmental problems caused by its production? Which method of generating electricity might help to solve our future energy problems in a practical and environmentally friendly way?

Procedure

1. Choose an alternative form of electrical production or a refinement of a common form of production that interests you.
2. Using the Internet, reference books, or other resource material, collect information about your chosen method of electricity production.
3. Display or present your findings in a format that has been approved by your teacher.

What Did You Find Out? Analyzing and Interpreting

1. As part of your research, find answers to the following questions.
   - **(a)** What equipment, facility, special conditions, or technology does your method of electricity production require?
   - **(b)** Is this method of electricity production currently being used? Is so, where and by whom? If not, why?
   - **(c)** What impacts, positive or negative, would your method have on the environment?
   - **(d)** What challenges does the development of this method present? (Hint: challenges could be related to such areas as pollution control, energy conversion efficiency, energy transmission, environmental impact, cost/completion, and consumer demand.)

TOPIC 8 Review

1. Describe one environmental concern that can arise for each of the electric power generation methods listed below.
   - (a) hydro-electric
   - (b) nuclear
2. Of the steps involved in producing electric light from coal, which could result in damage to the environment? Explain your choices.
3. For each environment-damaging step mentioned in question 2, describe steps that could be taken to reduce the impact on the environment.
4. Which of the alternative ways of producing electricity would be the easiest and most productive to implement in Alberta? Explain your answer.

Wrap-up

TOPICS 6-8

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

- electric generator
- magnetism
- electromagnet
- domains
- alternating current (AC)
- alternators
- direct current (DC)
- dynamo
- power
- watt
- hydro-electric plants
- non-renewable resources
- fission products
- nuclear fission
- thermonuclear
- flare gas
- rotor
- stator
- transformers
- circuit breakers
- fuse
- neutral wire
- hot wire
- ground wire
- short circuit
- open pit mining
- scrubbers
- greenhouse gases
- thermal pollution
- cogeneration
- geothermal energy

Reviewing Key Terms

1. In your notebook, match the description in column A with the correct term in column B

A	B
• a device that converts mechanical energy into electric energy	• power (6)
• a generator that produces direct current	• dynamo (6)
• a metallic conductor with a lower melting point than that of the conducting wires	• electric generator (6)
• antipollution systems that remove sulfur dioxide from factory smokestacks	• stator (6)
• energy per unit time	• service panel (7)
• a two-pole electromagnet in an electric motor	• fuse (7)
• technology used to "step up" the voltage of an alternating current travelling over long distances	• transformers (7)
• technology that channels the power entering a home to different circuits	• circuit breaker (7)
• unwanted heat that is released into the environment	• ground wire (7)
• uninsulated copper wire	• scrubbers (8)
	• thermal pollution (8)
	• geothermal energy (8)

Understanding Key Concepts

2. Describe the difference between AC and DC. Describe the way(s) in which each form of current electricity is produced. (6)

3. How do hydro-electric plants produce electricity? (6)

4. Describe the function of each of the following electric motor parts. (6)

(a) split ring commutator

(b) armature

(c) brushes

5. Which type of light bulb is more efficient, an incandescent light bulb or a fluorescent light bulb? Explain your answer. (7)

6. In your home, what part of an electricity panel acts as a safety switch that cuts off power if necessary? How does the appropriate component achieve this? (7)

7. What is the process that involves two small atoms coming together to form a larger atom? How could this process be used to produce electricity?(8)

8. What is a kilowatt hour? Provide the formula that would be used to calculate this value. (7)

9. What happens when a "short circuit" occurs? Describe what might cause a short-circuit. (7)

10. Explain what thermal pollution is, how electricity generation might cause it, and why it is a problem. (8)

UNIT 4

Ask an Expert

For the past six years, Su Ling Chong has been involved in a research project at the University of Alberta. Along with a neurophysiologist, mechanical engineer, and system developer, Su Ling works as the medical clinician in a fascinating project that allows people in wheelchairs to use electronic stimulation to propel themselves. This invention means that people who cannot use their leg muscles will have the opportunity to exercise them and stay active.

Q **Have you always been interested in science?**

A Yes. I had great science teachers in schools, and in grade eleven I participated in the Science Olympics and in the Women in Scholarship engineering Science and Technology program (WISEST). As a result, I got the opportunity to participate in an actual research project for six weeks in the summer.

Q **How did you become involved in the wheelchair project at the U of A?**

A As a clinician working with the elderly, I was always very interested in wheelchairs. The community rehabilitation program in which I was working in 1997 was being cut back and I noticed the job posting for a part-time physiotherapist working with electrical stimulation. I got the job. My role in this project is to provide clinical expertise on the wheelchair, determine a subject's suitability to participate, co-ordinate monthly testing and other required appointments, and help analyze the results.

Q **How long has this design been in development?**

A About five or six years. We took all the feedback from our subjects for each of our wheelchair prototypes and continued to improve on it. Biomotion, a medical device manufacturing company, bought the intellectual property from the University of Alberta and has been providing all the prototypes for our research.

Q **Why is this wheelchair unusual?**

A A standard wheelchair allows people to use only their feet on the ground to move along. Paralyzed people are not able to do this at all. They have to use their arms to propel the wheelchair, which may cause overuse injuries in the shoulders. As well, people who have weak leg muscles may not be able to propel effectively with their feet on the floor. This new wheelchair allows people with poor standing balance, weak leg muscles, or an injured spinal cord to drive the wheelchair easily.

Q **How does the wheelchair work?**

A The wheelchair is a standard manual wheelchair with a modified footrest. The footrest is linked to a gear system under the wheelchair, which drives the wheelchair. Users' feet are strapped to the footrest and they propel the wheelchair by bending and straightening their knees. There is a rod on the left side of the wheelchair in the shape of a seven that they can steer with. They can use their hands to help propel the wheelchair when going up ramps. For users who are paralyzed, electrical stimulation is used on their legs to stimulate the muscles that bend and straighten the knees to propel the wheelchair.

Q How does the electronic stimulator on the wheelchair work?

A The brain activates muscles in the body by sending electrical impulses to the spinal cord down to the nerve that stimulates the muscles. With spinal cord injuries, the electrical impulses from the brain do not get through, so a person is unable to move his or her legs voluntarily. The custom-made stimulator provides these electrical impulses to the muscles through electrodes placed over the motor points — that's where the nerves are the most superficial in the muscle.

Q How does this stimulation propel the wheelchair?

A It can stimulate up to eight muscle groups at the same time or alternately. Once we find all the motor points of the desired muscles for stimulation, we make a cuff to keep the electrodes in place. The user then has only to put on the cuff and the electrodes will be in the right positions. We use three rectangular electrodes on the top of the thigh for the quadriceps muscles and two or three electrodes on the bottom of each thigh for the hamstring muscles. In the "functional" mode, the stimulator is connected to the wheelchair.

Q How do the muscles know when to react?

A When the knees are bent in the resting position, the signal of the knee angle is sent to the Bio8 unit from the wheelchair to stimulate the top thigh muscles to straighten the legs. When the quadricep muscles are stimulated, the legs straighten. Once the knees have straightened or reached a threshold level that we have set, the signal is sent to stop the quadricep stimulation and to start the hamstring stimulation to bend the knees. These leg movements drive the wheelchair. The cycle is repeated until the muscles fatigue or the user stops the stimulation.

Q What does this design mean for people confined to wheelchairs?

A The implications of this method of propelling are wide. It prevents chronic wear and tear of the shoulder muscles, and it can prevent osteoporosis in the leg bones or increase bone density in the legs. The design helps users maintain muscle tone and muscle bulk and prevent atrophy in the legs while providing good circulation in the legs. It also requires less effort to propel the wheelchair than using the arm-propelled model, and it is easier for users to navigate slopes because they can use both their legs and their hands to propel the wheelchair. Lastly, it's a good cardiovascular workout if the wheelchair is used for long distances.

EXPLORING Further

You have been reading about an electronic wheelchair that enables paraplegics to move their legs. You may also have heard of devices such as electronic pacemakers that help to regulate irregular heartbeats. How do such devices work? What is the connection between electricity inside and outside the body?

How are electrical charges produced and transmitted in the human body? How do they help to keep the human body functioning? Conduct some research into the human nervous system and prepare a report, including diagrams, based on your findings. See if you can find out how positive and negative charges occur in the nervous system.

UNIT 4 PROJECT

My Amazing Electrical Invention

Over the past century, countless electric devices have been invented to meet a wide variety of human needs. As needs change and new technologies are developed, we will have the opportunity to experience many new electric inventions in the future. What would it feel like to be the inventor of a new electric device? How would you go about its development and construction?

Challenge

You will be part of a team that sets out to design and then construct your own amazing electric invention. Your team's invention must be constructed using only the materials approved by your teacher and must meet the Design Specifications listed below.

Materials

Supplied by student teams:

- assorted chemical cells
- electric components from used or discarded toys, electronics equipment, and small appliances (bulbs, LEDs, motors, wire, buzzers, rheostats, etc.)
- materials for invention construction (wood, plastic, cardboard, hinges, pulleys, nails, tacks, screws, glue, etc.)
- tools for construction (hammers, glue guns, pliers, wire cutters, screwdrivers, etc.)

Supplied by the school:

- ammeter
- voltmeter

Depending on supplies at hand, the school may supply:

- D-cells and holders
- cell holders
- copper wire
- Nichrome™ wire
- wire cutters
- bulbs and receptacles

Safety Precautions

- Wear proper eye protection at all times
- Have your list of materials and your plan approved by your teacher before proceeding.

Design Specifications

Your invention must:

A. have a "useful" function that can be easily communicated by your team

B. be self-contained and portable; no size restrictions (within reason) exist

C. be constructed of materials deemed "safe" by your teacher (commercial "electronics kits" may not be used)

D. have electric components installed in one circuit

E. be powered by a DC power source that does not exceed 9V

F. incorporate a minimum of three different types of loads (two bulbs count as one type of load)

G. have at least two separate switches, one of which controls all components while the other(s) control an individual component

H. have a component capable of varying resistance within the circuit

I. function properly in at least two out of three tests

Plan and Construct

1. Brainstorm with your team members to identify a possible function, or functions, for your invention.
2. Draw a prototype blueprint or design diagram that includes proper circuitry symbols for the electrical components. Each team member must contribute a drawing.

3. As a team, choose the design or combination of designs that will best meet your requirements.
4. Present a single labelled diagram of the chosen design to your teacher for approval.
5. Construct your invention.
6. Test, troubleshoot, and evaluate the functionality of your design throughout the construction process.
7. Measure and record the electric current and voltage of your entire circuit, with your "variable resistor" at different settings.
8. Each team member must draw a labelled scientific diagram of the team's invention and a correctly labelled circuit diagram of the electrical components of the device. Note: Be sure to include the symbols for an ammeter and voltmeter at the positions in your circuit where they were connected.

Evaluate

Part A

Invention Evaluation (Shared by All Team Members)

Demonstrate your inventions operation for your teacher, explaining how each design criteria has been met. Based on the construction process your group followed and the performance of your invention, copy and then fill in the following scoring chart.

Part B

Individual Analysis/Understanding of the Circuit Constructed (Individual Mark)

1. Record your team's measured values for current and voltage next to your circuit diagram. Using this data, calculate the resistance within your circuit (show all work and include units).
2. What type of circuit did you construct (series or parallel)? Explain how you know it is this type. Why did your group choose this type of circuit?
3. Describe where your group placed the switches for your device. Explain why they were positioned this way.
4. Which types of energy were produced and used by the various components in your invention? (State energy conversions, e.g., electrical to mechanical.)
5. What type of component did your group use to vary resistance? Why did you install the variable resistor where you did, and how did it affect the operation of your invention?
6. State whether your invention passed the testing procedure. Describe what aspects of the design and/or construction process were least difficult and which were most difficult.

Catagory	Criteria	Score	
		Student Self-Evaluation	Teacher Evaluation
Planning Process	Initial Individual Diagram Final Group Plan	/5 /5	/5 /5
Construction Process	General Preparedness of group/individual Efficient Use of Time by group/individual	/5 /5	/5 /5
Specifications	Inclusion of Required Components Successful Operation	/10 /10	/10 /10
Aesthetics/Appearance	General Apperance Ease of operation (convenience)	/5 /5	/5 /5
	Total Score	/50	/50

UNIT 4 Review

Unit at a Glance

- Excess electrons on an object create a negative charge. A shortage of electrons creates a positive charge.
- The Laws of Charge state that
  - (a) unlike charges attract
  - (b) like charges repel
  - (c) charged objects attract uncharged (neutral) objects
- Conductors allow electric charge to move freely. Insulators prevent charge from moving freely.
- The basic parts of all electric circuits are a source of electric energy, conductors, a load, and a control device.
- Quantity of charge is measured in coulombs.
- Current is measured in amperes.
- Voltage (potential difference) is a measure of the energy of a standard unit of charge, and is measured in volts.
- Resistance is the property of substances that hinders charge motion and converts electric energy in to heat. Resistance is defined as the ratio of voltage to current (Ohm's Law).
- A series circuit has one current path. A parallel circuit has more than one path along which current can flow.
- Thermocouples convert thermal energy to electric energy.
- Piezoelectric materials generate a small voltage when the pressure on them changes.
- Photovoltaic (solar) cells convert light energy to electric energy.
- Alessandro Volta observed that two different metals in a solution could generate a voltage. These observations led to the development of electrochemical cells and batteries, which consist of several cells connected together.
- Electric generators convert mechanical energy to electric energy. Their operation is based on the relationship between magnetism and electricity.
- Direct current (DC) flows in only one direction. Alternating current (AC) reverses direction periodically.
- The power grid generates and distributes AC electricity using transformers to change voltage for efficient power transmission.
- In homes, electric current travels through an electric meter and a service panel to branch circuits. Circuit breakers or fuses in the service panel cut off excessive current before wiring can overheat.
- Electric power is the product of voltage and current. Power measures the quantity of energy transfer each second.
- All electric devices convert some input energy into waste heat, so they are not perfectly efficient.
- Most of Canada's electric energy is generated using dams, thermo-electric plants that burn fossil fuels, and nuclear reactions.
- All methods of producing electricity affect the environment. Renewable sources of electric energy include biomass fuels and solar, wind, tidal, and geothermal energy.

Understanding Key Concepts

1. What does it mean to say a conductor is "grounded"?

2. Describe how positive and negative unbalanced charges are produced.

3. Why must electrostatic buildup in machinery be prevented? Give at least two examples to support your answer.

4. How does resistance within a series circuit change when more bulbs are added. Explain your answer.

5. Explain how piezoelectricity produces electric current.

6. Describe at least three factors that would affect the electrical production of a photovoltaic cell.

7. Which "batteries" used in daily life are actually not batteries? Explain your answer.

8. Describe one advantage and one disadvantage of a hydrogen fuel cell.

9. Draw a labelled diagram of the main parts of a thermo-electric generating station.

10. What is the main function of the stations and sub-stations located along the power grid? Why is this function necessary?

11. Describe the appearance and function of each of the three wires found within a cable commonly used for home wiring.

12. Draw a circuit drawing of a bedroom that contains two lights controlled by a switch, four plug-ins that constantly have power, and a closet with a light and its own switch that runs independently of the rest of the room. (You will need to invent a symbol for the plug-ins.)

13. What is the electrical efficiency of a 100 W light bulb that produces 5.7 kJ (57 000 J) of heat when it is on for 10 min? (Hint: remember that the bulb is supposed to produce light.) Show your work.

14. Why do we need to find alternative methods of producing electricity?

Developing Key Skills

15. Bob charged objects A and B by rubbing them together. Once charged, Bob moved object B close to a third object, object C, and made the following observations. For each observation below, answer the accompanying question.

    (a) Object **B** was attracted to object **C**. If object **B** is known to be negatively charged what is the charge of object **C**?

    (b) Object **C** was also attracted to object **A**. What is the charge of object **C**?

    (c) Based on the observations above, what is the charge of object A?

16. In your notebook, draw a circuit diagram for a circuit containing, two cells, one bulb and one switch.

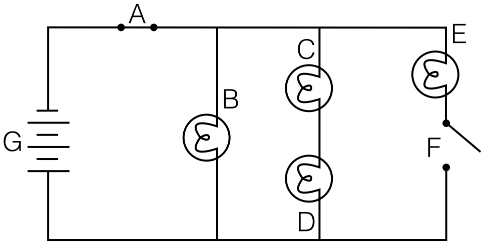
17. Describe at least three conditions that must be met in order for the bulb in the circuit in question 2 to light.

18. **(a)** If the voltage in the circuit drawn for question 2 was 3.0 V and the bulb had a resistance of 24 Ω, how much current would be flowing through the circuit?

    (b) If the number of cells was increased to four, what would the current be?

19. Describe three different ways in which chemical energy could be converted to electricity.

20. Examine the circuit diagram below and then answer the questions that follow.



(a) How many batteries are shown in the circuit above?

(b) Which of the bulbs would presently be on the way the circuit is pictured?

(c) If bulb C were to burn out and switch F was closed, which bulbs would be lit?

(d) In what direction are the electrons flowing in the above diagram? (clockwise or counterclockwise) Explain your answer.

Problem Solving/Applying

21. How many 100 W bulbs would a family have to remove in order to save $25.00 in a 30-day month? The bulbs are on for an average of 6 h per day and electricity costs $0.11 per kWh. (Please show your work.).

22. Glenda wishes to run several metres of speaker wire from the upstairs stereo to her downstairs bedroom. Describe at least three measures Glenda should take to ensure that her bedroom speakers receive the strongest signal possible. Explain each of your suggestions.

23. Shavez works in a factory that constructs highly sensitive computer components. Damage to their product due to electrostatic discharge (ESD) is of great concern to the owners of the company. Describe three different measures that Shavez or the owners could take that would decrease the chances of product damaging ESD.

24. Describe three positive ways in which people make use of electrostatic phenomenon.

25. Why do most power plants produce alternating current rather than direct current?

26. Describe how you could determine whether a string of holiday lights was wired in parallel or series.

27. Describe two advantages of wiring a circuit in parallel and two advantages of wiring a circuit in series.

28. Draw a circuit diagram of a circuit that would allow you to vary the brightness of two bulbs wired in parallel. The circuit should include a two-cell battery and one switch that controls the entire circuit.

29. In a voltaic cell, what is the function of the following components?

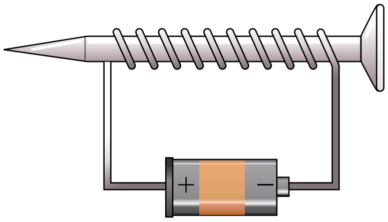
(a) negative electrode (anode)

(b) positive electrode (cathode)

(c) electrolyte

Critical Thinking

30. Use the diagram below to answer the following questions.



(a) Why does the iron nail become a magnet when the battery is connected?

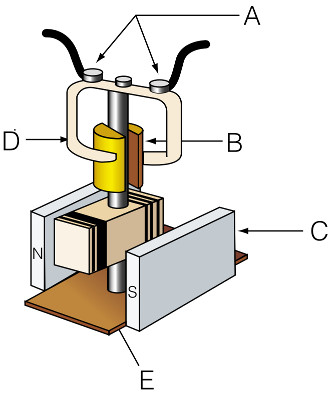
31. Describe the energy conversions that take place in a:

(a) hydro-electric power plant

(b) thermo-electric (fossil fuel) power plant

(c) nuclear power plant

32. Examine the diagram of the St. Louis motor shown below. In your notebook, identify the parts indicated by letters on the diagram. Describe the function of each labelled part.



33. Howard wishes to reduce his electric bill by installing solar cells on the roof of his house. Describe some factors Howard must consider before undertaking this project.

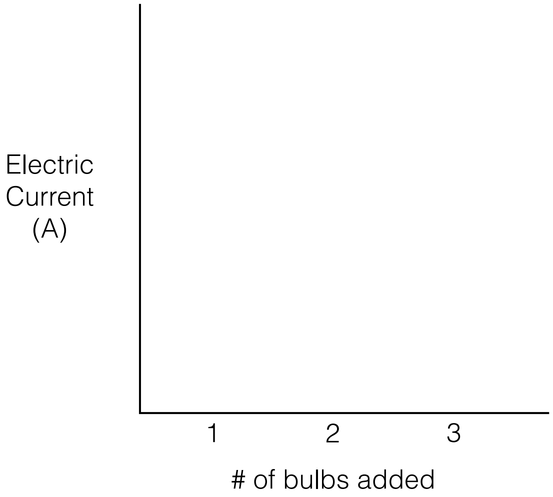
34. Describe three alternative ways of producing electricity that have minimal impact on the environment. Explain the reasons for your choices.

35. Explain why each of the alternative methods for producing electricity that you mentioned in question 35 are not as commonly used as the traditional sources of electricity.

36. What would the power rating (in watts) be for a vacuum cleaner that requires 12 A of current from a 120 V circuit? How many joules of energy would the vacuum use in 10 min of use? (Show your work.)

37. What is the electrical efficiency of an electric water heater (with a power rating of 6300 W) that can raise the temperature of 151 L of water 10°C in 15 min (Hint: it takes 4180 J to raise the temp of 1 L of water 1°C)?

38. What happens to the electric current flowing within a parallel circuit compared to the electric current flowing within a series circuit when more bulbs are added? Illustrate your answer by copying the axis illustrated below into your notebook. Plot a line that represents the series circuit electric current and another that represents the parallel current.



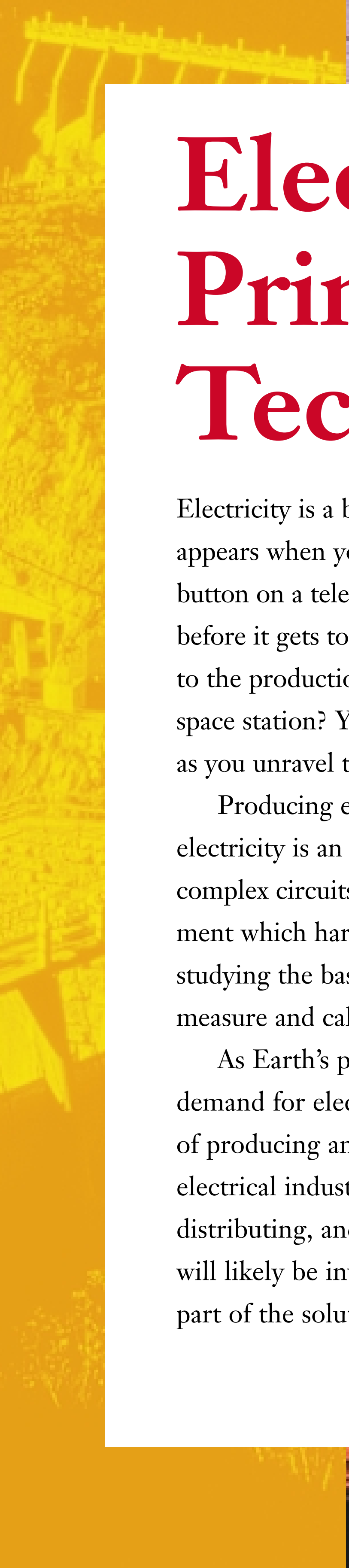
Hint: Include a legend and use a different coloured line to indicate each circuit type.

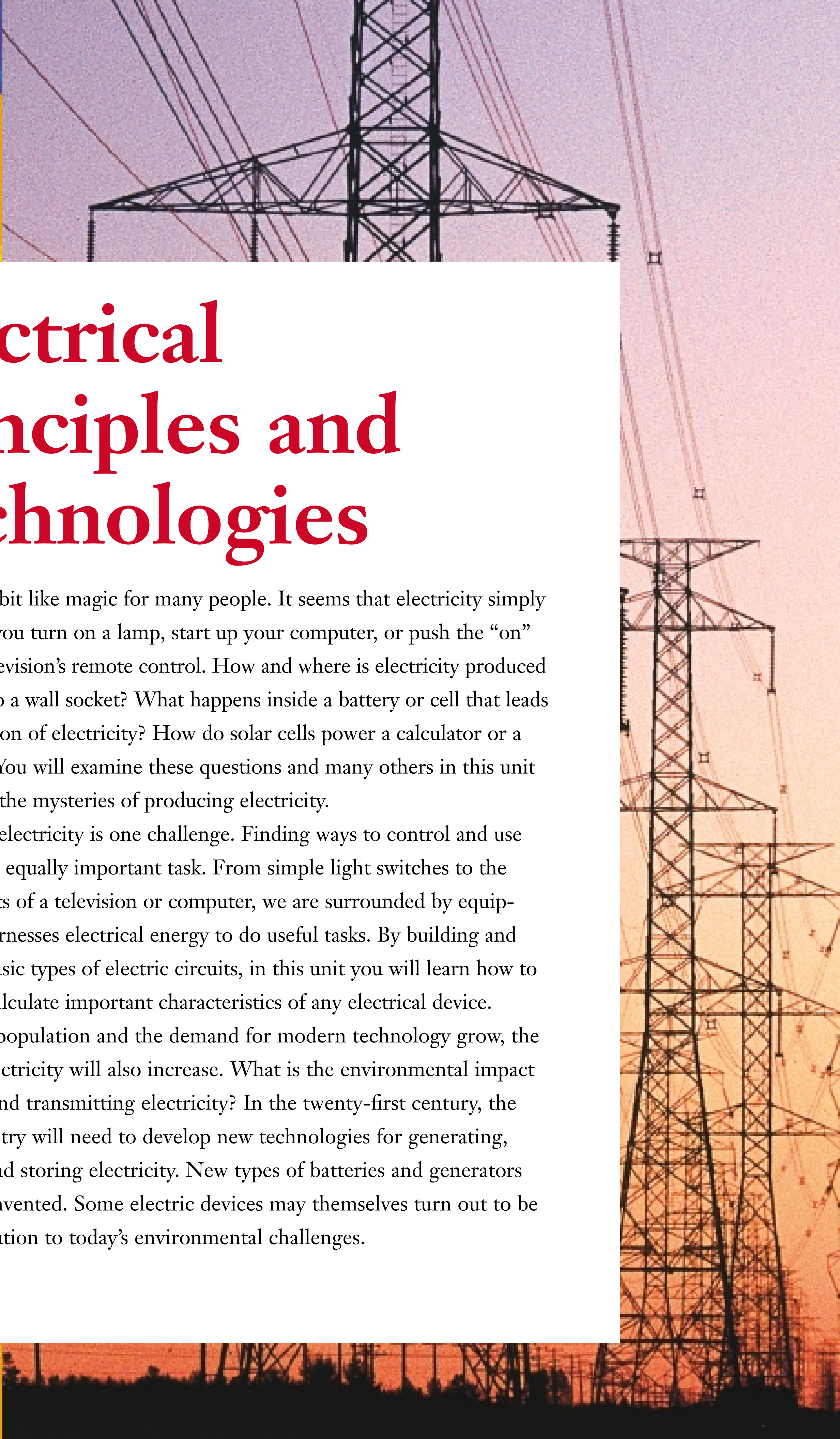
39. What is the main source of electricity for the province of Alberta? Give reasons why this method is so popular, and identify some of its advantages.

Pause& Reflect

Go back to page 264 at the beginning of this Unit, and check your original answers to the Focussing Questions. How has your thinking changed? How would you answer those questions now that you have investigated the Topics in this Unit?

UNIT 4



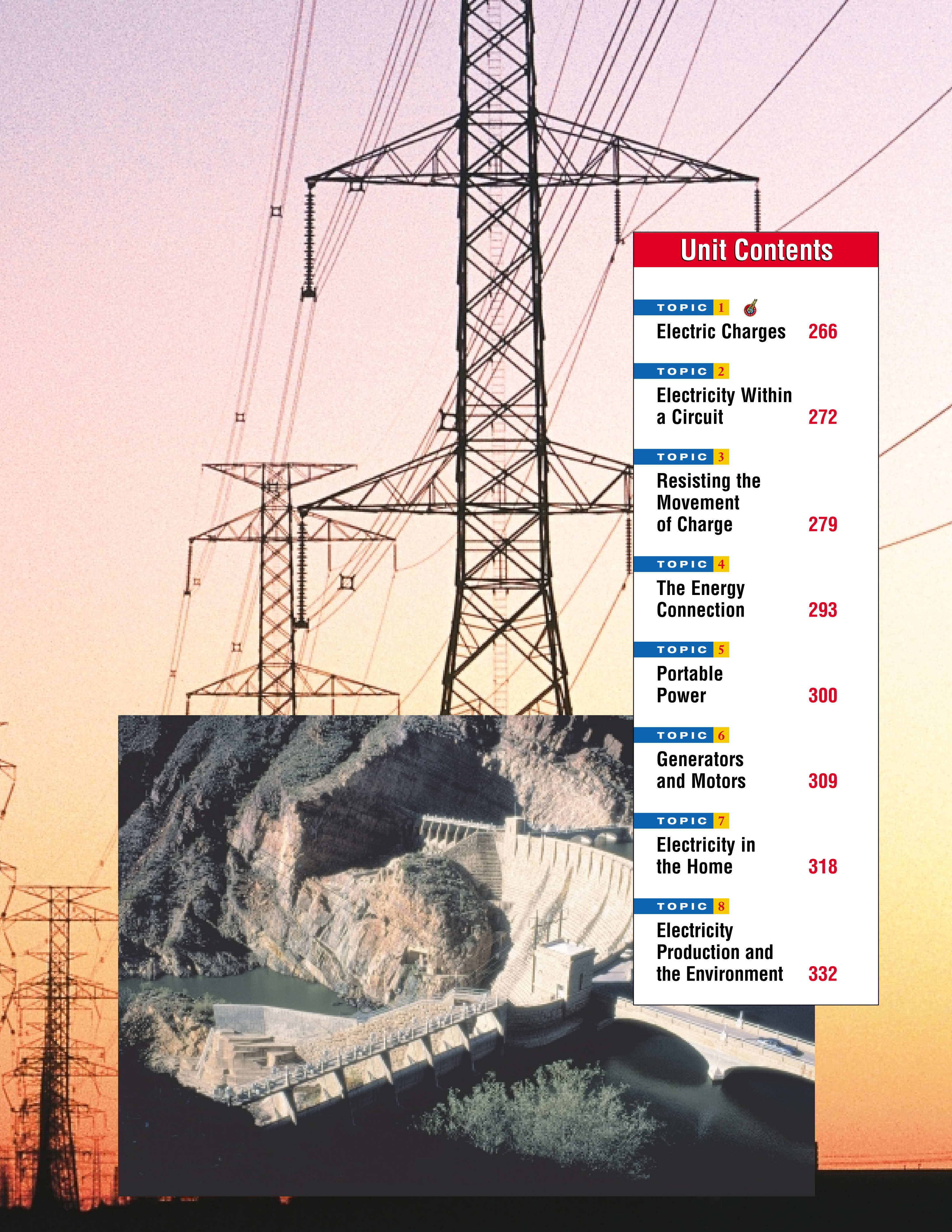


Electrical Principles and Technologies

Electricity is a bit like magic for many people. It seems that electricity simply appears when you turn on a lamp, start up your computer, or push the "on" button on a television's remote control. How and where is electricity produced before it gets to a wall socket? What happens inside a battery or cell that leads to the production of electricity? How do solar cells power a calculator or a space station? You will examine these questions and many others in this unit as you unravel the mysteries of producing electricity.

Producing electricity is one challenge. Finding ways to control and use electricity is an equally important task. From simple light switches to the complex circuits of a television or computer, we are surrounded by equipment which harnesses electrical energy to do useful tasks. By building and studying the basic types of electric circuits, in this unit you will learn how to measure and calculate important characteristics of any electrical device.

As Earth's population and the demand for modern technology grow, the demand for electricity will also increase. What is the environmental impact of producing and transmitting electricity? In the twenty-first century, the electrical industry will need to develop new technologies for generating, distributing, and storing electricity. New types of batteries and generators will likely be invented. Some electric devices may themselves turn out to be part of the solution to today's environmental challenges.



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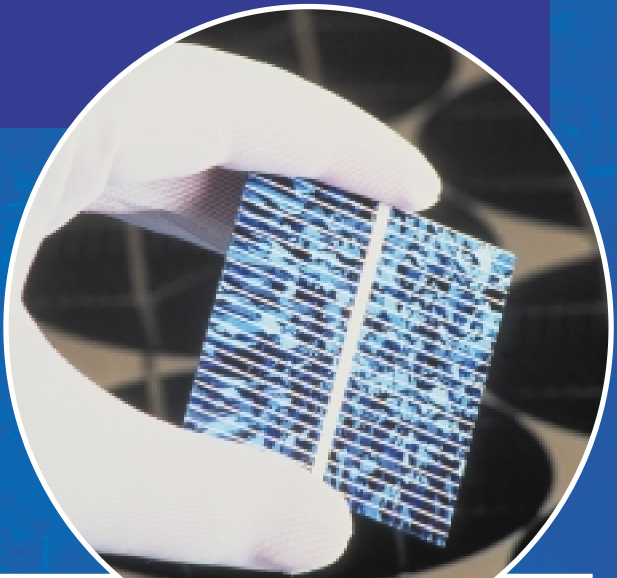
UNIT 4 Preview

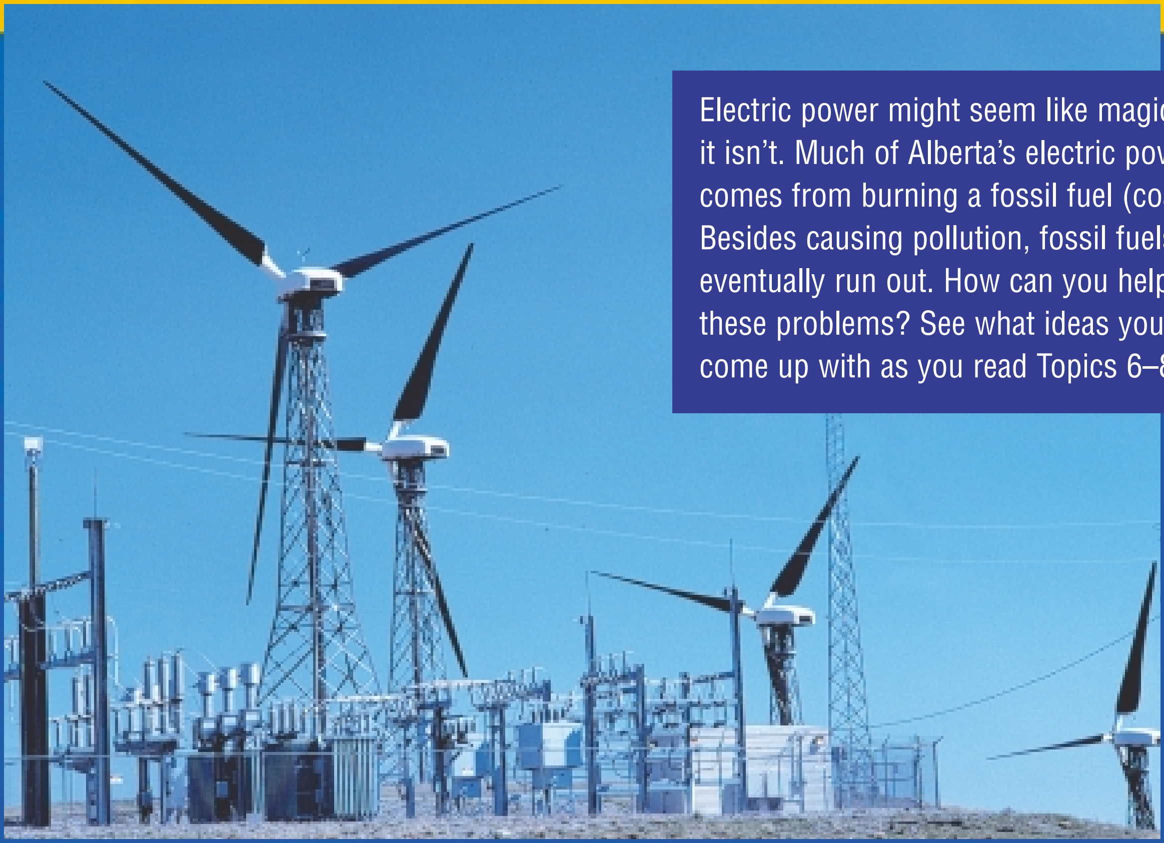
Focussing Questions

- How do we turn coal in the ground or water behind a dam into electric energy that you can use in your home?
- How are we able to control the energy so that the various appliances we use receive just the right amount?
- What new technologies can we develop to help us use energy in less environmentally demanding ways?

Hey presto! Bring an electric charge into existence! Make the charge do some work for you. Now make it stop. And find out when electric charges can be a nuisance for people and machinery. You can do all of these things by reading Topics 1–3.



Is it possible to use chemical energy to produce electricity? Can you produce electricity by using light? And when you've figured out how to do that, can you find a way to store the electricity until you need it? You'll be able to do all of these and more after reading Topics 4–5!

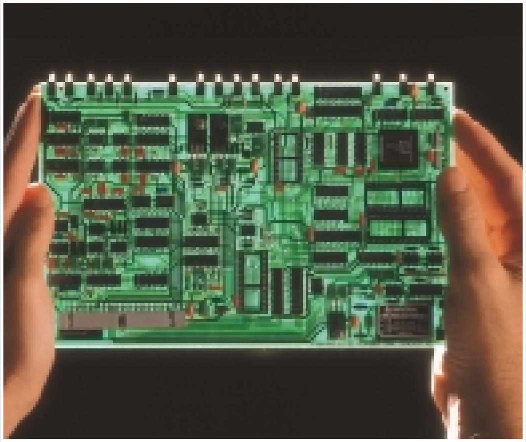


Electric power might seem like magic, but it isn't. Much of Alberta's electric power comes from burning a fossil fuel (coal). Besides causing pollution, fossil fuels will eventually run out. How can you help solve these problems? See what ideas you can come up with as you read Topics 6–8.

Looking Ahead

Look ahead to pages 346–347, My Amazing Electric Invention. In this project, you will work with a group to invent and build your own electric device based on the principles you learned throughout the Topics. As you work through the unit, pay close attention to information about electric devices and components that may help you invent and build your device. You may want to

- draw several designs for possible devices as you learn about loads, circuits, resistors, and other electrical principles
- use a paper or electronic file to keep track of important information that could aid in making your invention work
- discuss your design ideas and knowledge about electricity with your group members



TOPIC 1 Electric Charges

Storm clouds roll in on a summer evening. Suddenly the sky is split by an enormous lightning bolt, far too energetic to harness or control. By comparison, sparks created when you comb your hair, or the electrical currents created by a battery, are tiny indeed. Scientists have, however, developed a unified explanation for all these phenomena: the idea of electric charge. The electrical devices you use everyday, from lightbulbs to computers, use the energy of moving charges to do useful work. This Topic will introduce you to the theory and laws of electric charge.

Find Out ACTIVITY

Charge It

Many combinations of materials, such as shoes on carpets and clothes in a dryer, will become electrically charged when they are rubbed together. How do charged and uncharged objects react to each other? Can you come up with a set of rules that could describe their behaviour?

Materials

watch glass (at least 10cm diameter)
2 acetate strips (at least 12 cm long)
2 vinyl strips (at least 12 cm long)
1 sheet of paper towel

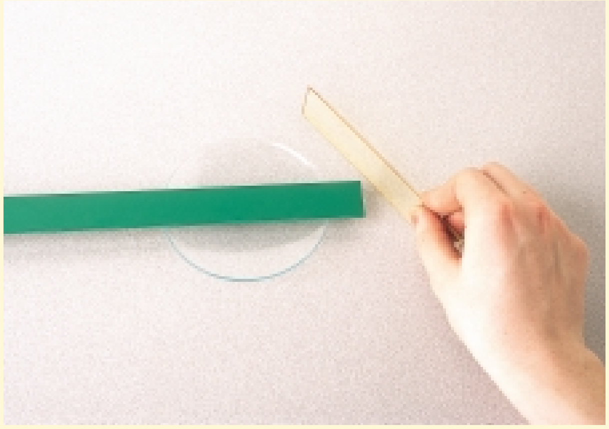
Procedure ✴ Performing and Recording

1. Copy the observations table and then experiment to complete it.
2. Just before each trial, remove any charges from the watch glass or any "uncharged" strip by gently wiping them with your hand.
3. Charge plastic strips by pulling them gently through a folded paper towel several times.
4. Balance one strip on the watch glass without letting it touch the table or anything else.
5. Move the handheld strip near one end of the balanced strip. Note any movement. If the strips touch, you will need to recharge them.

Trial	Strip balanced on the watch glass	Hand-held strip	Behaviour of balanced strip (attracts, repels, nothing)
1	uncharged acetate	uncharged acetate	
2	uncharged acetate	charged acetate	
3	charged acetate	charged acetate	
4	charged acetate	uncharged vinyl	
5	charged acetate	charged vinyl	
6	charged vinyl	charged vinyl	
7	uncharged vinyl	uncharged vinyl	

What Did You Find Out? **Analyzing and Interpreting**

1. Describe the behaviour(s) you observed between:
   (a) two uncharged strips.
   (b) two charged strips.
2. Were the behaviour(s) between charged strips always the same? Explain either why they were the same, or why they were different.
3. Write three rules that describe the possible behaviours that occur when objects with different charges are brought close to each other.



Producing Charges

Materials that attract and repel other materials are said to be charged, or carry an electric charge. It is these charges that were being collected when you rubbed the plastic strips with paper towel in the Find Out activity. The charge is responsible for the change in the material's characteristics after rubbing or touching. In the Find Out Activity, for example, the plastic strips were able to attract or repel each other if one or both of them became electrically charged.

How are electric charges produced? Many combinations of materials become charged when they are rubbed, touched, or moved close together and then separated. Think, for example, of shuffling across a carpet. Both you and the carpet develop an electric charge. As a result, your body behaves differently when you touch a door handle or another person. You receive an electric shock, and may even notice a spark — a tiny bolt of lightning. In a thunderstorm, water droplets and ice crystals in the clouds are buffeted by the strong winds, colliding and rubbing against each other. When you walk across a room, your shoes or socks rub against the carpet.

Cool Tools

Electric charge can be detected by an instrument called an electroscope. Pocket-sized electroscopes called dosimeters are used to measure exposure to atomic radiation. Charged particles produced by the radiation are detected by the dosimeter. There are strict limits to the amount of radiation exposure that workers may receive.

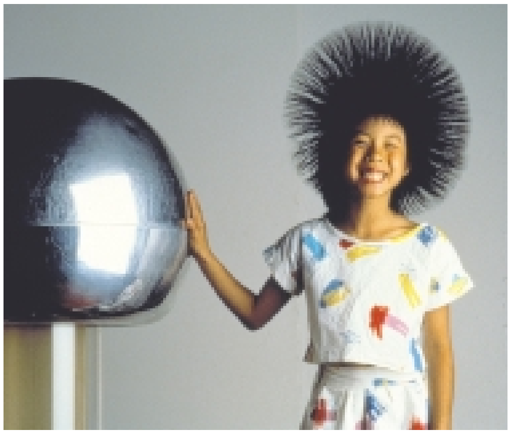


Figure 4.1 A Van de Graaff generator produces large electric charges on a metal sphere. How can you tell that the girl touching the generator has also become electrically charged?

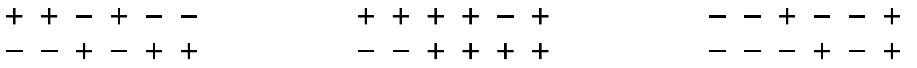
In many cases, charges produced by rubbing or touching remain stationary, so they are sometimes called **static electricity**. There are, however, many instances when these charges move, so **unbalanced charges** is a more accurate way of describing the phenomenon.

It is difficult to measure electric charge directly. Fortunately, that is seldom necessary, because the amount of charge can usually be calculated from other measurements. The quantity of electric charge is expressed in coulombs (C). A bright light bulb, for example, allows about 1 coulomb of electric charge to pass through it every second.

Making Sense of Electric Charges

As you have discovered, charged objects attract neutral objects. Some charged objects repel each other, while others attract each other. There are three interactions to be explained. Scientists explain these interactions in terms of positive and negative charges in the materials themselves.

Figure 4.2 The charge on an object depends on the balance between positive and negative charges in the object.



(a) neutral ("uncharged") equal positive and negative charge

(b) positive charge excess positive charge

(c) negative charge excess negative charge

Pause & Reflect

In your Science Log, explain whether electrons would need to move onto or off an object in order to charge the object negatively. How could an object be charged positively by moving electrons?

American inventor and politician Benjamin Franklin (1706–1790) was the first to use the terms “positive” and “negative” to describe charges. Franklin called the charge on amber that had been rubbed with fur *negative*. The charge left on the fur was called *positive*. Two different charges, one positive and one negative, are called *unlike* charges. Two charges of the same type (both positive or both negative) are called *like* charges. Benjamin Franklin lived before scientists understood that all matter consists of atoms, which in turn contain positively charged particles (protons) and negatively charged particles (electrons). According to modern theory, unbalanced charges on solid materials are due to the movement of electrons from one object to another. Even without this knowledge, however, Franklin’s experiments helped establish the **Laws of Charges** that describe the behaviour between charged and uncharged objects.

1. Unlike charges attract.
2. Like charges repel.
3. Charged objects attract uncharged (neutral) objects.

Conductors, Insulators, and In-Between

For many materials, such as rubber, a charge stays on the spot where you rub the object. Such materials fit into a class called **insulators**. Insulators are materials that do not allow charges to move freely on or through them. Materials that allow charges to move freely, are classified as **conductors**. Most metals are conductors and most non-metals are insulators.

Since electrons are the charges that move through solids, a conductor must be a material that holds its electrons loosely. Insulators, on the other hand, are materials that hold their electrons very tightly. Some materials are not perfect insulators, but they are not good conductors either. These "fair conductors" allow electrons to move, but not at all freely. Table 4.1 classifies some common materials by their electrical conductivity.

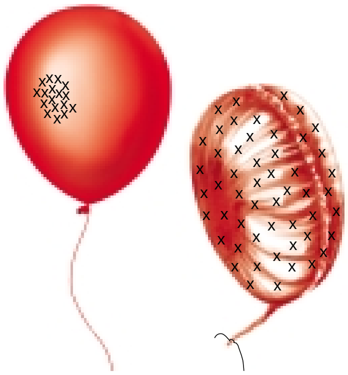


Figure 4.3 When you rub a rubber balloon, the charges (x) remain in place. When you rub a metallic balloon, the metal conductor allows the charges to move freely over the entire surface.

Table 4.1 Some Common Conductors and Insulators

Good Conductors	Fair Conductors	Insulators
aluminum	silicon	cotton
copper	carbon	glass
gold	human body	paper
nickel	humid air	plastic
platinum	nichrome	porcelain
silver	water (salty)	rubber
tungsten		water (pure)

Pause& Reflect

In your Science Log, list several common applications for materials with each type of electrical conductivity. Where would you expect to find good conductors, fair conductors and insulators being used in typical electrical devices like lights, calculators, extension cords, and stoves?

Semiconductors are materials with higher conductivity than insulators but with lower conductivity than metals. Their conductivity is often increased by implanting foreign atoms into the otherwise pure material. Two commonly used semiconductors are silicon with gallium added and germanium with phosphorus added.

Superconductors are materials that offer little, if any, resistance to the flow of charges. Certain materials become superconductors when they are subjected to extremely low temperatures — about –137.15°C to –273.15°C. Superconductors are usually made of metal alloys and ceramics. Some applications of superconductors include components for electric generators, high-voltage power lines, and supercomputers. Superconductors take up less space and can carry higher charges than ordinary conductors. In one power transmission application, about 114 kg of superconducting wire replaced about 8200 kg of copper cable, making it more than 7000% more space efficient.

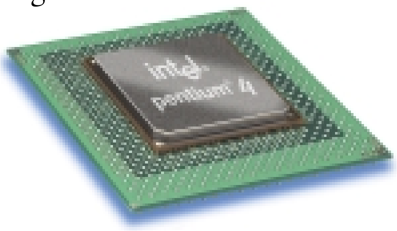


Figure 4.4 Silicon semiconductors are used extensively to make computer microchips.

Neutralizing Unbalanced Charges

Have you ever battled "static cling" when removing clothing from a drier on a dry day? You probably felt, and even saw, small sparks—an electric **discharge**—as accumulated charge on the clothing was **neutralized** (became balanced). Electric discharges are a serious safety hazard, because they can shock people, damage electronic equipment, and cause fires and explosions. Their cause is simple. In a discharge, electrons either enter an object to make up for a shortage, or an excess of electrons leaves the object.

Connecting an object to Earth with a conducting wire — **grounding** the object—is an easy way to neutralize conductive materials. Earth is so large that it can easily supply enough electrons to neutralize a positively charged object. Similarly, Earth can absorb extra electrons from a negatively charged object.

Non-conductors, or insulators, usually must be neutralized with ionization. Ionization devices produce both positive and negative ions. These ions are attracted to materials with an opposite charge, transferring charges until the material is neutralized. Ionizers come in a variety of sizes and shapes ranging from small hand-held devices to large wall-mounted models that are installed in manufacturing facilities.

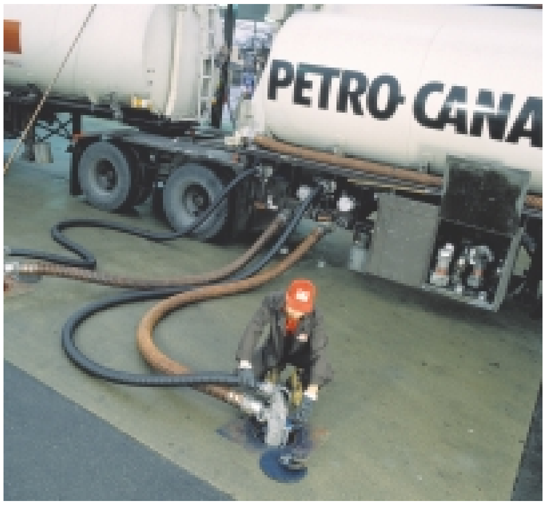


Figure 4.5 When a gasoline truck rolls down the highway through blowing wind and dust and over bumpy roads, it often becomes charged. Before the truck delivers gasoline, it is grounded. This prevents sparking that could cause gasoline fumes to explode. The movement of gasoline through the hose also produces charges, so the grounding cable must remain attached during the delivery, as well as before it starts.

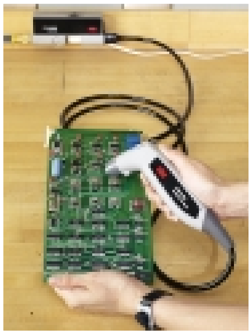


Figure 4.6 Hand-held ionizers can neutralize electrostatic charges on non-conductors.

Preventing Electrostatic Buildup

Buildup of unbalanced charge can be costly, even if there is no electric discharge. Charged objects attract dust and contaminants. They also stick together and jam equipment such as photocopiers. To decrease static buildup, antistatic sprays and coatings can be applied to carpets and other surfaces on which charge accumulates. After materials have become charged, sprays can also be used to dissipate (scatter) the charge (see figure 4.7).

Electronic components like computer memory cards are especially sensitive to electrostatic discharge, so they are often shipped in special antistatic packaging. Before handling sensitive components, electronic technicians may fasten a "grounding strap" on their wrist. The strap contains conductive materials, so that when one end is grounded, any unbalanced charge on the technician's hand or body is neutralized without harmful electric discharge.

Figure 4.7 Coatings and sprays are applied to surfaces to prevent buildup of charges and to dissipate charges that are already present.

Find Out **ACTIVITY**

Putting Electrostatics to Work

The understanding of how positive and negative charges interact has led to many useful applications for electrostatics.

Materials

poster paper
drawing, writing, and colouring supplies
reference sources, such as the Internet, school library, and resource people

Procedure

Communication and Teamwork

1. Choose a topic that interests you in the field of applications of electrostatics. You might consider electrostatics in painting, farming, negative ion generators, electrostatic precipitators, photocopiers, how electrostatic air filters clean the air in homes and hospitals, how fabric softeners reduce static cling, or how electrostatics is used in studying living cells. Phrase your topic in the form of a question, plan the steps of your research, and discover the answer. Present your information orally to the class, using visual aids, such as posters or a multimedia presentation.

What Did You Find Out?

1. What surprised you about the information you learned in your research?
2. List all the technologies presented by classmates. What additional questions do you have about the applications of electrostatics? List at least three questions you would like to answer.

You have seen how the attraction between positive and negative charges can be harnessed and put to use in a variety of technologies. When the movement of electric charge is controlled within conducting wires, many other fascinating technologies become possible. In Topic 2 you will deepen your understanding of electricity by investigating electric circuits.

TOPIC 1 Review

1. List the three “Laws of Charges.” For each law, give an example of the law being applied.
2. Describe the difference between a negatively charged object and a positively charged object.
3. Why is the phrase “unbalanced charges” a more accurate way of describing the phenomena we often refer to as “static electricity”?
4. How do charged conductors and insulators differ from each other? Name two examples of conductors and two examples of insulators.
5. Describe two different ways in which a charged object can be discharged.
6. **Apply** Describe a situation in which electrostatic discharge could pose a problem. Explain how the problem could be solved. Describe an application that uses electrostatic charges in a positive way. Explain how the charges are used.
7. **Thinking Critically** What do you think would happen if you rubbed two identical objects together? Would they attract each other, repel each other, or neither attract nor repel each other? Why?

TOPIC 2 Electricity Within a Circuit

Have you ever looked inside a computer or television? Electronic devices, especially older ones, are a maze of mysterious parts connected by a tangle of different coloured wires. No matter how simple or complex, however, every electric **circuit** provides a continuous pathway for charges to move. In the next activity, you can experiment with a very simple circuit, and find out how the energy of moving charges can be harnessed.

Figure 4.8 Electronic devices often contain hundreds of parts, connected in carefully designed circuits.

Find Out ACTIVITY

Light That Bulb?

In past studies you may have experimented with wires, bulbs, switches, and cells in order to come up with an arrangement that will light the bulb. What requirements must the circuit meet? What role does each component play in a simple circuit?

Materials

2 D-cells (without holders)
4 copper wires (with alligator clips)
1 knife switch
1 3.7 V bulb (without holder)

Safety Precautions

Procedure ✷ Performing and Recording

1. Arrange and connect all of the supplied components so the bulb lights. Draw a simple sketch that illustrates how you constructed your circuit.
2. Arrange all of the supplied materials in at least four additional different configurations that also allow the bulb to light. Make and sketch at least one circuit design with:
   - **(a)** the switch at a different location.
   - **(b)** the cells in a different location or alignment.
   - **(c)** the bulb connected in a different manner.

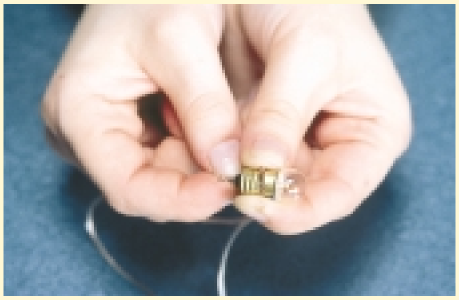
What Did You Find Out? ✷ Analyzing and Interpreting

1. Describe all of the requirements that a circuit must meet in order to light the bulb.
2. List at least three possible explanations for a situation in which the bulb did not glow.
3. Does electricity have to travel through the bulb in a particular direction in order for it to glow? Give evidence from this activity that supports your answer.
4. What role does the switch play in the circuit? How does it carry out this role?

Extension

Study the rules on the next page for drawing a proper circuit diagram. Using this information draw a diagram of a working circuit that includes two cells, two bulbs, and a switch that controls

- **(a)** both bulbs.
- **(b)** only one of the 2 bulbs



Circuit Elements and Diagrams

Even the most complex circuits are made up of only four basic elements, or types of components (Figure 4.9).

- *Source:* The source of electric energy.
- *Conductor:* The wire through which current flows.
- *Load:* Items along the circuit that convert electricity into other forms of energy (for example, light bulbs, motors, heaters, and speakers).
- *Control:* A switch or device that can turn the circuit or devices along it on or off.

Pause& Reflect

Make a table in your Science Log to record the symbols and names of circuit components. Record the symbols in Figure 4.9. Leave room to add to your list as you learn more symbols in your study of electric circuits.

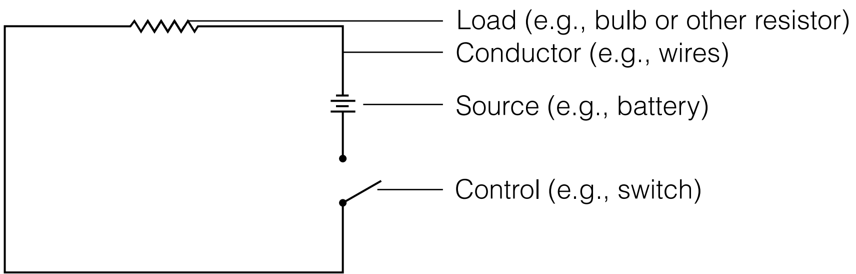


Figure 4.9 Basic components of electric circuits.

You have worked with three laboratory components of an electric circuit: a dry cell, a lamp or light bulb, and a conducting wire. Figure 4.10 shows the circuit symbols for these three components and for several other components.

The cell symbol stands for a single dry cell or a wet cell (you will study wet cells later in this unit). A **battery** is a combination of cells. You can use a **switch** to “open” or “close” a circuit to control the current through it. The **resistor** symbol is used to represent one of many different **loads**. One load is used so much in laboratory work that it has its own symbol: the lamp. Circuit diagrams are drawn in a standard way designed to make them simple and easy to prepare and read. Your circuit diagrams should meet the following criteria.

Word CONNECT

The term “battery” describes two or more cells connected together. D, C, AA, and AAA “batteries” are more accurately called cells. Car batteries, large 6 V flashlight batteries, and small rectangular 9 V batteries are all correctly labelled as batteries since they contain more than one cell.

- Draw with a pencil and ruler on graph paper or unlined pages.
- Place components in a rectangular or square arrangement.
- Make conductors straight lines with right-angled ("square") corners.
- If possible, arrange your diagram so conductors do not cross.
- Draw neatly, making symbols a consistent size.

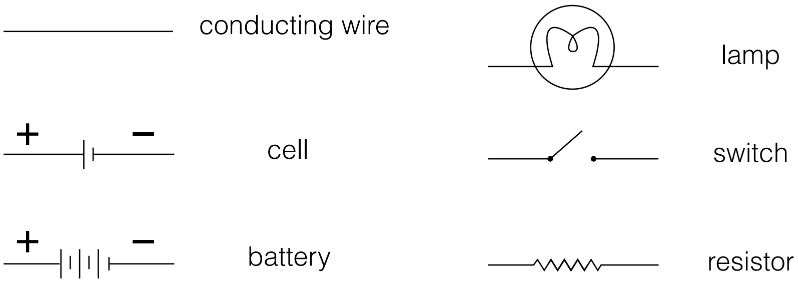


Figure 4.10 Circuit symbols are similar to words; they make communication quick and accurate.

Measuring Current

Imagine a fast-flowing river. If you were to describe the current you might state the number of litres of water that flow past a certain point every minute. Similarly, scientists describe electric current as the amount of charge that passes a point in a conducting wire every second. The symbol for current is *I*. Electric current is measured in **amperes** (A) or milliamperes (mA) (see Table 4.2). Currents in common electric devices range from a few milliamperes to dozens of amperes (see Table 4.3).

Table 4.2 Symbols and Units for Current

Quantity	Symbol	Unit
Current	*I*	ampere (A) milliampere (mA)
Time	*t*	second (s)

Table 4.3 Current in Household Appliances

Appliance	Current (A)
radio	0.4
100 W lamp	0.8
colour television	1.7
toaster	8.8
microwave oven	11.7
electric kettle	12.5
electric range	40

An instrument used to measure very weak electric current is called a **galvanometer**. Larger currents are measured with an **ammeter** or milliammeter. Figure 4.11 shows typical laboratory models of these instruments. The symbols for these instruments are a circle with "G," "A," or "mA" in the centre, respectively. You will use current and ammeters in the next investigation.

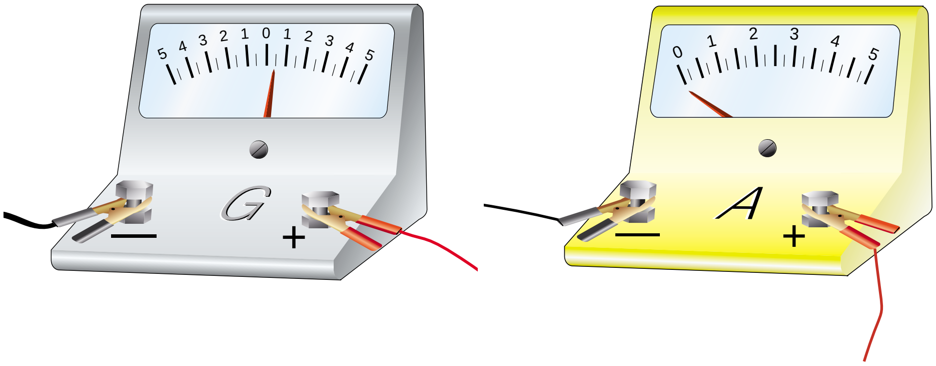


Figure 4.11 A galvanometer (left) and ammeter (right) both measure electric current.

Pause& Reflect

Start a table in your Science Log for symbols and units, like the one shown in Table 4.2. Each time you encounter a new unit, add it to your table.

DidYouKnow?

The galvanometer is named after Luigi Galvani (1737–1798), an Italian scientist who first recorded the presence of electric current. A galvanometer can accurately measure both the direction and strength of an electric current. The first galvanometers were based on a discovery made by Hans Oersted in 1819. He observed that a magnetic compass needle rotated slightly when electric current flowed in a nearby wire.

Skill FOCUS

For more information about using ammeters and voltmeters, turn to Skill Focus 14.

Measuring Voltage

Energy for pushing electrons is available if positive and negative charges are separated. A battery, for example, forces electrons to accumulate at one terminal (connection), making it negatively charged. At the same time, electrons withdraw from the other terminal, leaving it positively charged. In a battery, energy from chemical reactions does the work of separating the charges (see Figure 4.12). The energized electrons now have the ability to do work on something else, such as lighting a bulb or heating a burner on a stove.

All forms of energy are measured in joules (J). However, when describing the energy of electrons in an electric circuit, we describe the energy possessed by a standard unit of charge instead of the total energy of all of the charges. As well, we always compare one point in a circuit to another. The term **potential difference** means the difference in energy per unit of charge between one point in the circuit and another point in the circuit. Potential difference is commonly referred to as **voltage**.

The standard unit for potential difference is the **volt** (V), named after Alessandro Volta (1745-1827), who built the first battery. Most electrical devices require potential differences of 1 to 120 V, but higher voltages are not uncommon (see Table 4.5). Voltage is measured with a **voltmeter**, such as the one shown in Figure 4.13. In circuit diagrams, the symbol for a voltmeter is a circle with "V" at the centre.

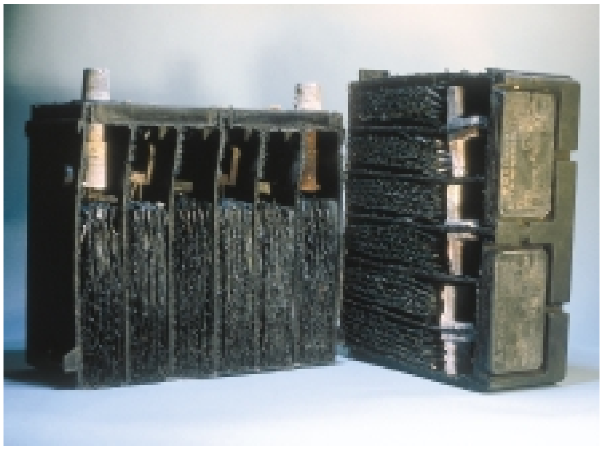


Figure 4.12 Chemical reactions inside the six cells of this car battery separate electrical charges, increasing their energy.

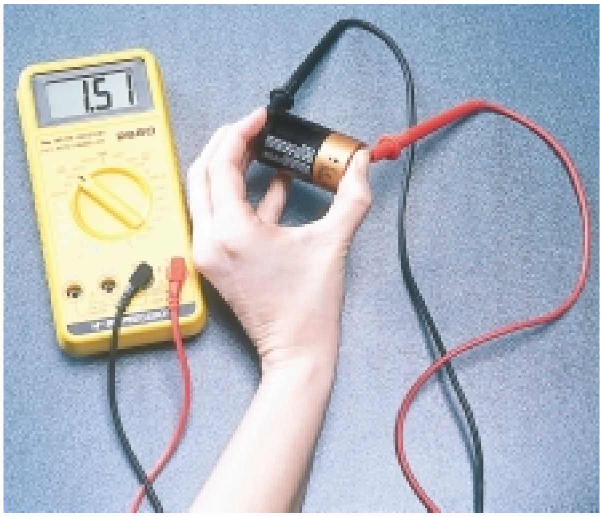


Figure 4.13 This digital multimeter can measure voltage, current, and other characteristics of electric circuits.

Table 4.4 Symbols and Units for Potential Difference

Quantity	Symbol	Unit
potential difference (voltage)	V	volt (V)
energy	E	joule (J)

Table 4.5 Voltage in Household Appliances

Energy Source	Voltage (V)
"AA"cell	1.5
household wall plug	120
electric stove wiring	240
television high-voltage supply	200 000

Pause& Reflect

Add the symbols and units for energy and potential difference (voltage) to the table in your Science Log.

INQUIRY

INVESTIGATION 4-A

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Current and Voltage

In this investigation you will construct a simple circuit and then use an ammeter and voltmeter to find out how the electric current and voltage (potential difference) vary at or across different points within the circuit.

Apparatus

ammeter
voltmeter
knife switch
2 D-cells in battery holder
2.5 V bulbs (2) in sockets
3.7 V bulb (1)
4 copper wires with alligator clips

Safety Precautions

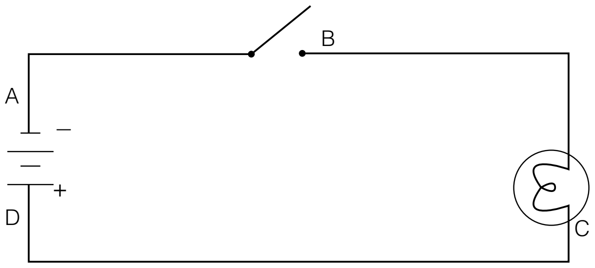
Part A: Measuring Current

Question

Does the electric current flowing through a circuit vary at different points within the circuit?

Prediction

Examine the diagram below and predict whether the electric current at points B, C, and D will be higher, lower, or equal to the current at point A.



Procedure

① Using the 3.7 V bulb, construct the circuit illustrated.

② Plan how to place your ammeter into the circuit. You must force all the current to flow through the ammeter to get to the rest of the circuit. The positive terminal of the ammeter must lead to the positive end of the battery.

③ Measure the current at point A with the switch open, and again with the switch closed. **Record** the ammeter readings in a copy of the current observations table.

④ Repeat step 3 at the points labeled **B**, **C**, and **D** on the circuit diagram.

Current Observations

Ammeter location	Electric current (mA)	
	Switch open	Switch closed
A		
B		
C		
D		

Analyze

1. Compare the electric current flowing out of the battery and into the battery (points A and D). Suggest an explanation for your observation.
2. Compare the current on either side of the bulb (points B and C).
3. What effect did opening and closing the switch have on the current?

Conclude and Apply

4. For an electric current to flow in a circuit, what conditions must exist?
5. Hypothesize about factors that affect the strength of an electric current in a circuit. If time permits (and with your teacher's permission), test your hypothesis.

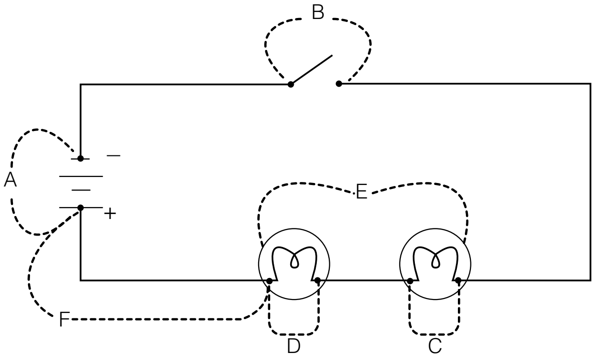
Part B: Measuring Voltage

Question

How does the voltage (potential difference) across different components within a circuit compare?

Prediction

Examine the diagram below and predict whether the potential difference (voltage) across points **B**, **C**, **D**, **E** and **F** will be higher, lower, or the same as the voltage across point **A**.



Procedure

1. Using the 2.5 V bulbs, construct the circuit illustrated.
2. Use the diagram to plan how to connect your voltmeter to the circuit. One lead from the voltmeter must be connected to each side of a circuit component. The positive terminal of the voltmeter must lead to the positive end of the battery.
3. Measure the potential difference (voltage) across point A when the switch is closed, and **record** the voltmeter reading in a copy of the voltage observations table.
4. Repeat steps 2 and 3 at the points labeled **B** , **C**, **D**, **E** and **F** on the circuit diagram.
5. Replace the 2.5 V bulb at point D with a 3.7 V bulb and measure the voltage at point D. Compare the brightness of the 3.7 V bulb with the original 2.5 V bulb.
6. Remove both bulbs and measure the voltage at point E.

Voltage Observations

Location of Voltmeter	Voltage(V)
A	
B	
C	
D	
E	
F	
D (with 3.7 V bulb)	
E (bulbs unscrewed)	

Analyze

1. Which parts of your circuit
   (a) provide electrical energy
   (b) use electrical energy?

2. Compare the potential difference (voltage) across the battery (A) to the voltage across the load (E).

3. How does the energy provided to the circuit compare to the energy used?

4. How does the potential difference across an individual bulb (C or D) compare to the voltage across the entire load (E)?

Conclude and Apply

5. How did the brightness of the 2.5 and 3.7 volt bulbs compare? Use your voltmeter readings to suggest an explanation for this difference.

6. How did the potential difference across point E change when the bulbs were removed? Suggest why.

Rivers of Electricity

Electric circuits are often compared to water systems. Electric charge flows through the parts of the circuit, just as water flows through pipes or along a river channel. The energy of the moving charge is changed to different forms as current passes through the load, just as the energy of moving water can be harnessed as it flows downhill. Study Figure 4.14 and identify the following points in each diagram:

(a) highest energy
(b) lowest energy
(c) control
(d) load

DidYouKnow?

An arrow labelled with the symbol e^- is often used to indicate the direction of electrical charge movement in a circuit. In solid conductors, the moving charges are electrons.

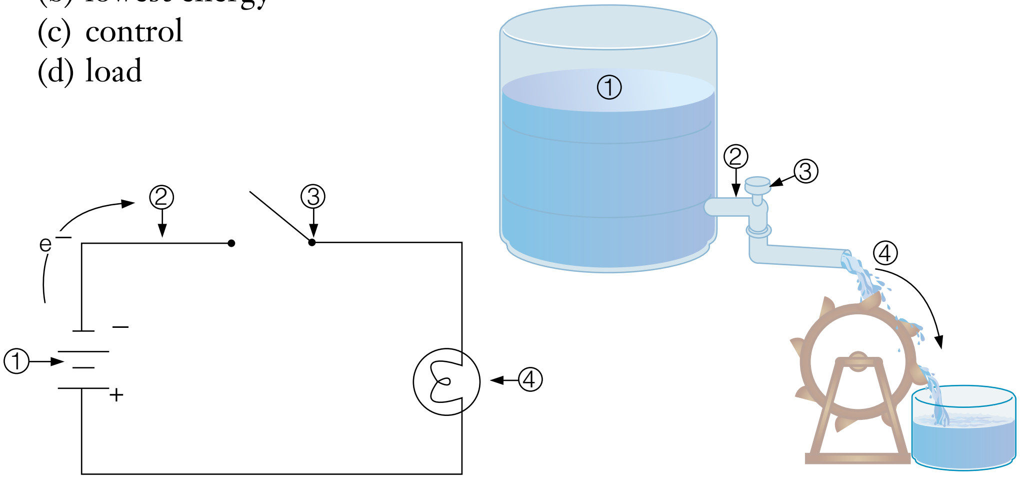


Figure 4.14 An electric circuit is similar in many ways to a water system.

TOPIC 2 Review

1. Copy the electric terms listed below into your notebook. Write the water (hydraulic) related term from the column of terms on the right that best typifies each electric term next to it. For each pair of terms, describe why you think they are similar.

(a) load	**(1)** pump
(b) switch	**(2)** pressure
(c) electric current	**(3)** pipe
(d) voltage	**(4)** water wheel
(e) battery	**(5)** valve
(f) conductor (wire)	**(6)** flow rate

2. Draw a circuit diagram using symbols. Include a battery, a switch, a lamp, an ammeter, and conducting wires. Add arrows to show the direction of the flow of electrons. Describe the function of each part of the circuit.

3. Explain how to connect a voltmeter to a circuit to measure the voltage across a light bulb. Use a sketch to clarify your explanation.

4. **Apply** Predict which current will be greater, the current passing through an electric iron or the current passing through an electric razor, when each is plugged into a 120 V outlet. Explain how you made your prediction.

5. **Thinking Critically** If a circuit contains a 12 V battery, a switch, and a light bulb, what is the voltage across the light bulb?

TOPIC 3

Resisting the Movement of Charge

Resistance is a property of a substance that hinders motion of electric charge and converts electric energy into other forms of energy. For example, the resistance of the tungsten wire filament in a light bulb is more than 400 times greater than the resistance of a similar copper wire. When current flows through the high-resistance filament of the light bulb, the filament converts much of the energy of the current into light and heat. If the same current flows through a copper wire, the amount of energy converted into heat is so small that you hardly notice it.

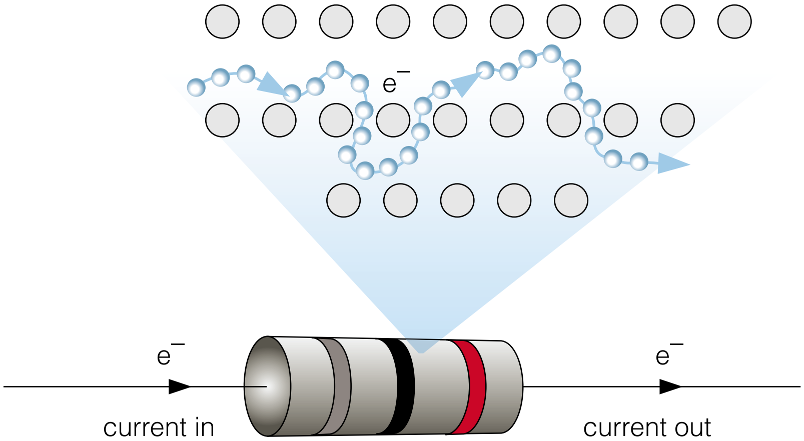


Figure 4.15 Negatively charged electrons must force their way through solids, overcoming resistance caused by the attraction of positively charged atomic nuclei and the repulsion of other electrons.

Within an electric circuit voltage, current, and resistance are closely related. If current is described as the movement of electrons through conductors, and voltage is what makes the electrons move, then resistance is what opposes the motion of the electrons.

The language of resistance can be tricky. A good conductor, like copper, allows electric charge to move easily through it. That is, a good conductor has *low* resistance. Poor conductors, on the other hand, oppose the movement of charge. In other words, poor conductors have *high* resistance. Just as in a game of golf or hearts, where the best players have the lowest scores, better conductors have lower resistance.

DidYouKnow?

Georg Ohm was the first person to publish results of experiments on the resistance of wires of various sizes. Ohm applied a voltage across wires of many different lengths and diameters, and measured the current through them. He discovered that, for each wire, the ratio of voltage to current stayed the same. Today, we would say that the *resistance* of the wires was constant. We would describe the wires as *ohmic resistors*.

Find Out ACTIVITY

Resistance Roadblock

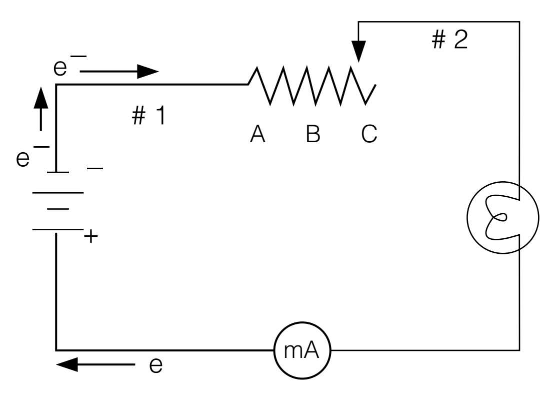
Some electronic components are made of materials that are poor conductors. Why would high resistance be useful in a circuit? How does increasing or decreasing the resistance within a circuit affect the energy of electrons moving in the circuit?

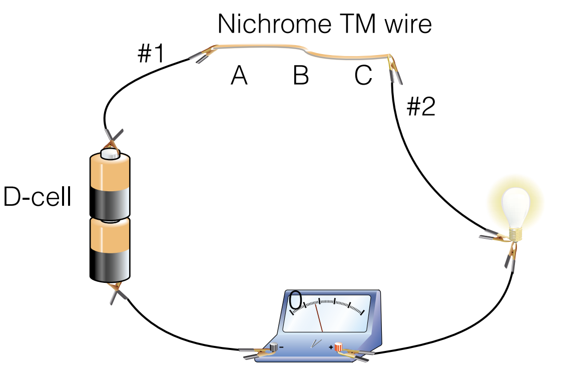
Safety Precautions

Handle the Nichrome™ wire carefully while it is connected to your circuit. It may heat up enough to cause minor burns.

Materials

1 m Nichrome™ wire
2.5 V bulb and holder
2 D-cells in holders
milliammeter
3 copper wires with alligator clips





Procedure ✷ Performing and Recording

1. Copy the table below into your notebook.
2. Complete the prediction portion of the table for different positions of lead #2 (clipped to the Nichrome™ wire).
3. Construct the circuit shown in the diagram.
4. Slide lead #2 to positions A, B, and C and record your observations of the brightness of the bulb and the reading from the ammeter.

Current & Bulb Brightness

Location of lead #2 on Nichrome™	Current (mA)		Bulb brightness	
	Predicted (low, medium, high)	Actual	Predicted (dim, medium, bright)	Actual
A				
B				
C				

What Did You Find Out? ✷ Analyzing and Interpreting

1. How did the amount of current change when you moved the clip and increased the length of Nichrome™ wire in the circuit?
2. In general, suggest how the amount of resistance in the circuit affects the electric current flowing through the circuit.
3. What does the brightness of the bulb tell you about energy of the electrons passing through it?

Extension

1. Into what form was electrical energy converted by the Nichrome™ wire? Give evidence to support your answer.
2. What items in your home offer resistance to the flow of electrons? How do you know?

The standard unit for resistance is the **ohm**, symbolized by the Greek letter omega (Ω). Electronic devices contain resistors with a huge range of values, from a few thousandths of an ohm (milliohms) to many millions of ohms (megohms). Resistance can be measured directly with an **ohmmeter**, but in practice, technicians are more likely to use a multi-purpose electronic measuring instrument (a "multimeter") set to measure resistance.

Calculating Resistance

As you saw in the previous activity, resistance affects the current flowing in a circuit. Resistance also affects the potential differences between different points in complex circuits with several loads. Georg Ohm found that it is possible to calculate the resistance of a circuit, or part of a circuit, from measurements of current and voltage. Can you see how this can be done from the measurements in Table 4.6?

Table 4.6 Resistance, voltage, and current in a simple circuit

Resistance (Ω)	Voltage (V)	Current (A)
1	1	1
1	10	10
2	10	5
5	10	2

Electrical resistance is calculated by finding the ratio of the voltage across the load (V) to the current through the load (I). Using R to represent resistance, the mathematical equation for resistance is

$$R = \frac{V}{I} \qquad \textbf{resistance} = \frac{\textbf{voltage (potential difference)}}{\textbf{current}}$$

According to this relationship, the units of resistance are volts per ampere *(V/A)*, which are equivalent to ohms. The expression above is called **Ohm's law**. Since Ohm's law can be solved for any of its variables, you will also see it expressed in these forms.

$$\text{voltage (potential difference)} = \text{current} \times \text{resistance} \quad V = IR$$

$$\text{current} = \frac{\text{voltage (potential difference)}}{\text{resistance}} \quad I = \frac{V}{R}$$

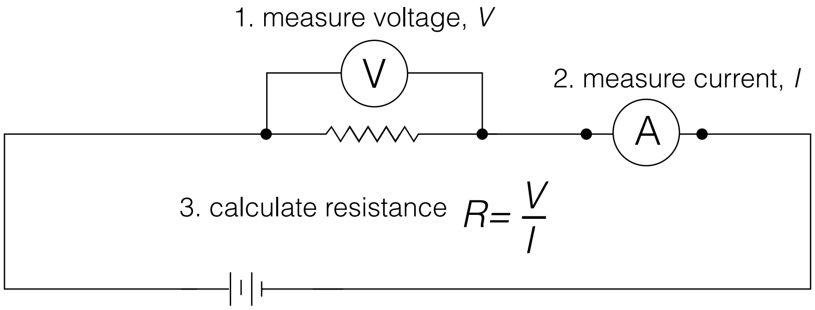


Figure 4.16 Ohm's law allows you to calculate resistance from current and voltage measurements.

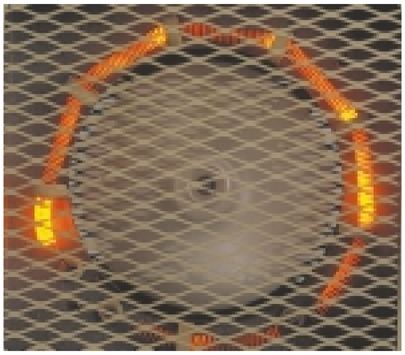
DidYouKnow?

A 100 watt light bulb has resistance of about 144 Ω when connected to a 120 V supply. Typical stereo speakers act as though they have a resistance of 2 Ω to 8 Ω to the current flowing through them. Many headphones and earbuds have resistance of 32 Ω. Dry human skin has resistance of about 500 000 Ω (500 kΩ or 0.5 MΩ).

Pause& Reflect

Add the symbol for resistance *(R)* and the unit ohm (Ω) to your table of symbols and units in your Science Log.

Model Problem



What is the resistance of an electric heater, if a current of 12.5 A runs through it when it is connected to a 120V wall outlet?

Given

$I = 12.5$ A
V = 120V

Required

Resistance, R, in ohms (Ω)

Analysis

Use the expression $R = \frac{V}{I}$ to find resistance.

Solution

$$\begin{aligned} R &= \frac{V}{I} \\ &= \frac{120\text{ V}}{12.5\text{ A}} \\ &= 9.60\ \Omega \end{aligned}$$

Paraphrase

The resistance of an electric heater is 9.60 Ω, if the current through it is 12.5 A, with a 120 V supply.

Practice Problems

Use an appropriate form of Ohm's law to solve each problem. Show your work for all questions.

1. What is the resistance of a light bulb if a 12 V battery sends a current of 2.4 A through it?
2. A toaster with a resistance of 145 Ω is connected to a 120 V source. What current will flow through the toaster?
3. What is the potential difference across a 1 500 Ω resistor carrying a current of 0.075 A (75 mA)?
4. **Apply** An extension cord rated at 15 A is connected to a 120 V supply. What is the *smallest* resistance with which the cord can safely be used?

Resistors

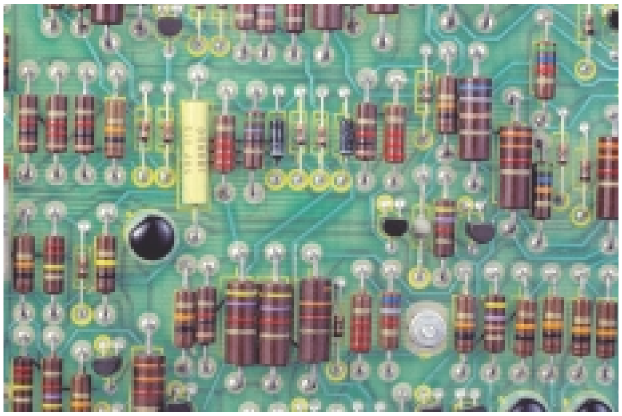


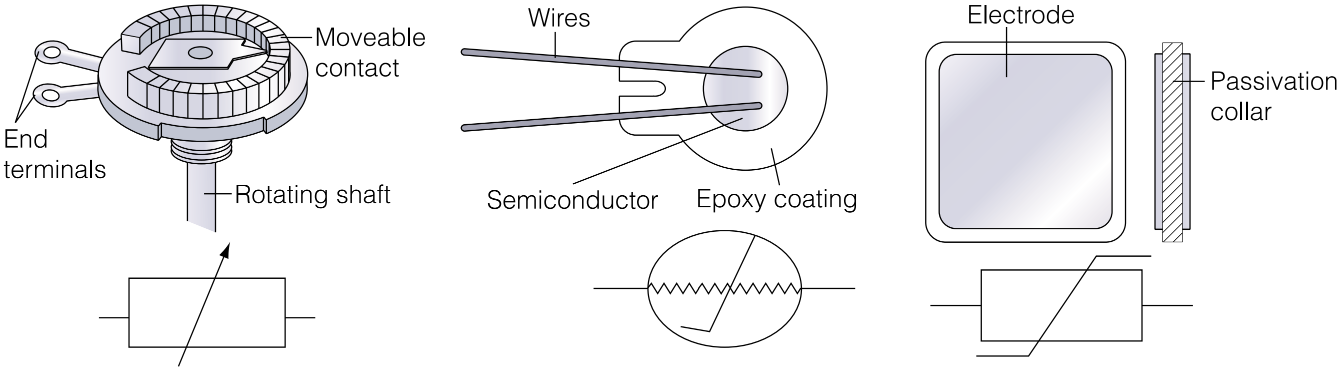
Figure 4.17 The coloured stripes on these resistors show their resistance and quality in coded form.

In electronic circuits, resistance is useful for more than changing the energy of moving charges into heat. One very common type of electronic component — the resistor — is used to control current or voltage to suit the specific needs of other electric devices in the circuit. Circuit resistors are usually made of a heat-conducting ceramic core coated with materials such as carbon, metal oxides, metal film, or resistance wire. Modern "chip" resistors are made of similar materials, but they are very small. Instead of being soldered into holes in a circuit board, as in Figure 4.17, they are mounted directly on the surface of the board.

Variable Resistors

Variable resistors do not have a fixed resistance. Instead, their resistance changes in response to temperature, light, voltage, or some other variable. The Nichrome™ wire that you have used in several activities acted as a variable resistor. When you changed the length of wire, you also varied the resistance in the circuit. Variable resistors are used in a wide variety of electronic devices, from simple light dimmers and motor speed controls to surge protectors and refrigerator and stove temperature controls.

Figure 4.18 Common types of variable resistors



(a) Rheostats have a slide-shaped armature that controls the total resistance. They are usually found in high-current electric circuits, such as power-distribution equipment.

(b) A thermistor is sensitive to changes in temperature. Thermistors are used in thermostats and heat sinks.

(c) Varistors are voltage-dependent resistors used in a circuit to protect it from high-voltage surges.

INQUIRY

INVESTIGATION 4-B

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Voltage, Current, and Resistance

Inside electronic devices such as CD players and radios you can find many small resistors. In this investigation you will examine the relationship between the electric current flowing through a resistor, the voltage across its ends, and the known resistance of the resistor.

Question

What is the relationship between resistance, the voltage across the ends of a radio resistor, and the electric current flowing through it?

Hypothesis

Use Ohm's law to suggest a general answer to the question.

Safety Precautions

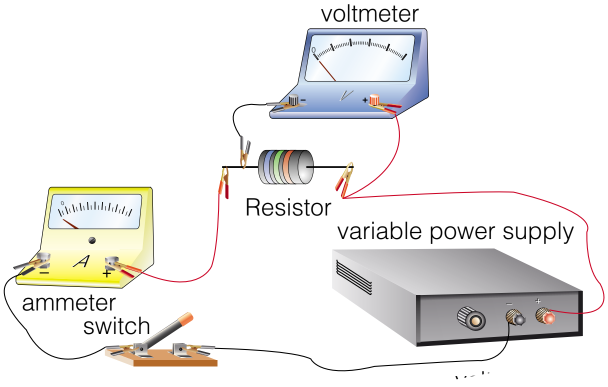
- Avoid touching resistors while current passes through them and immediately afterwards. They can get hot enough to burn you.
- Do not use the power supply to generate currents greater than 0.5A or voltages greater than 15V.

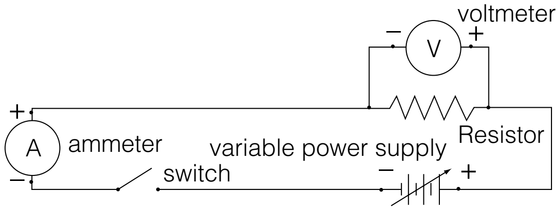
Apparatus

ammeter or milliammeter
voltmeter
variable low-voltage power supply or several batteries
6 copper wires with alligator clips
2 resistors (of different known resistance between 10 and 60 ohms)
switch

Procedure

1. Copy the table below into your notebook.
2. Construct a circuit similar to the one shown in the diagram.
3. Close the switch. Adjust the power supply until the voltmeter shows a convenient potential difference such as 1.0 V across the resistor. **Record** the exact voltage and the corresponding current reading on the ammeter.
4. Repeat step 3 an additional four times for voltages between 1.0 and 6.0 V.
5. Repeat steps 3 and 4 for a second resistor, using the same potential differences as previously.





Analyze

1. What happened to the amount of electric current as you increased the voltage?
2. For similar voltages, compare the amount of current passing through each of the resistors.

Conclude and Apply

3. Using Ohm's Law ($R = V/I$) calculate the resistance for each trial. Remember that if the potential difference (V) is in volts, current (I) must be expressed in amperes. If your current measurements are in milliamperes (mA), you can convert them to amperes by dividing by 1000.
4. For each resistor, how well do the five calculated values for resistance agree? Why are the calculated values not usually identical?
5. How well do the calculated resistance values compare to the value marked on each resistor? Suggest an explanation for any difference in the values.
6. How well do your results support Ohm's law? Give evidence to support your answer.

Extend Your Knowledge and Skill

7. Design an experiment to determine if a light bulb behaves according to Ohm's law. Obtain a light bulb from your teacher. Make the necessary measurement using a wide variety of voltages and currents.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Investigate a variety of resistor-related web sites where you can find out the latest in resistor design and innovations, as well as on-line guides to the resistor colour code. Use the code to find the rated resistance for some of the resistors you used in this Investigation. Visit the above web site. Go to the web site above, and click on Web Links to find out where to go next.

Electric Current, Voltage, and Resistance

Resistor # (Known resistance) (Ω)	Voltage (V) (V)	Measured Electric current (I) (mA)	Calculated Electric current (I) (A)	Calculated resistance (R) (Ω)
1 (known Ω)				
2 (known Ω)				

Types of Circuits

All the circuits you have constructed so far in this Unit have had a single source of current connected to a single load and, sometimes, a single control switch. In practice, electrical circuits are seldom that simple. Think of your home, for example. Lamps, televisions, stoves, refrigerators, computers, and many other devices operate from the same source of electric energy, yet each appliance seems to operate independently of the others. The circuits are constructed to allow each device to be turned on, while the others remain off. How is this done? You can find out by studying the two basic patterns for connecting several loads into a single circuit.

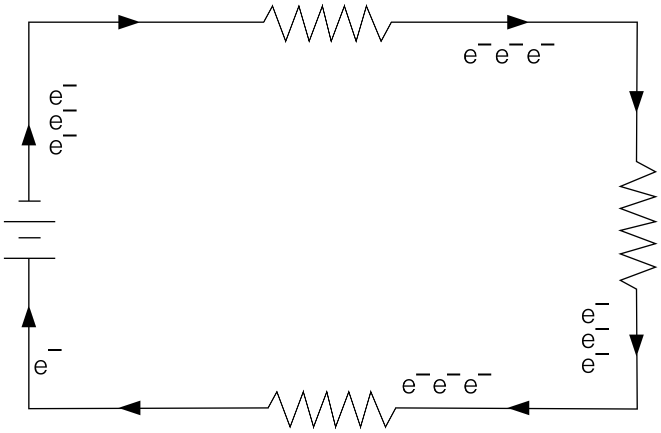


Figure 4.19 A series circuit has a single current path. These three loads are connected in series.

Series circuits have only one current path. All the moving charges travel through each component in the circuit. You can think of a series circuit as a set of parts connected end to end.

Parallel circuits have several current paths. The total current is divided, with some of the moving charges travelling through each **branch**, or part of the circuit. You can think of of a parallel circuit as a set of branches connected side by side.

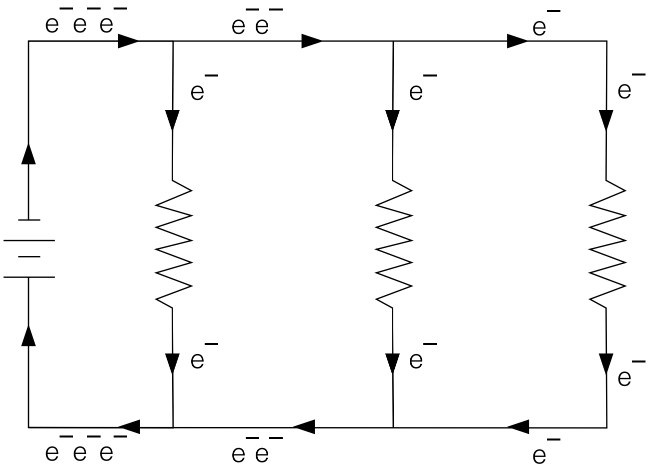


Figure 4.20 A parallel circuit has several current paths. These three loads are connected in parallel.

Each type of circuit—series and parallel—has specific characteristics that make it useful in certain situations. As well, circuits can be made with some parts connected in series, and others in parallel. Current sources, as well as loads, can be connected in series and in parallel. You may investigate these complex situations in future courses.

INQUIRY

INVESTIGATION 4-C

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Series and Parallel Circuits

Depending on the requirements of a circuit, it may be wired in series or in parallel. You will explore the advantages and disadvantages of each type of circuit in this investigation.

Question

How does adding extra bulbs affect the other bulbs in a series or parallel circuit?

Hypothesis

Write a hypothesis that answers the questions for each type of circuit. In your data tables, predict what will happen to the other bulbs as bulbs are added to either circuit. How will the addition of bulbs affect the amount of current flowing through the circuit?

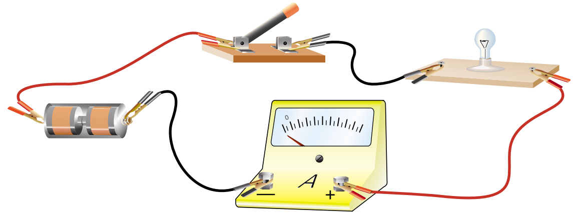
Safety Precaution

Apparatus

2 1.5 V D-cells and cell holders
3 3.7 V bulbs with holders
7 wires with alligator clips
1 ammeter
1 switch

Part A: Current and Brightness in a Series Circuit

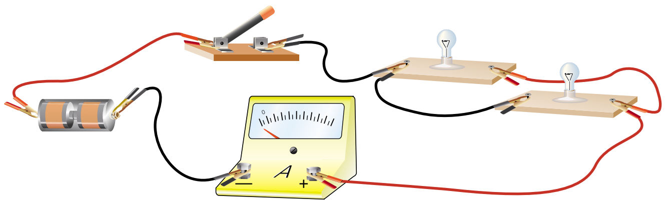
Series circuit layout	Predicted brightness	Observed brightness	Current (A)
1 bulb			
2 bulbs			
3 bulbs			
3 bulbs, 1 unscrewed			



Part A

Part B: Current and Brightness in a Parallel Circuit

Series circuit layout	Predicted brightness	Observed brightness	Current (A)
2 bulbs			
3 bulbs			
3 bulbs, 1 unscrewed			



Part B

CONTINUED ▶

Part A: Series

Procedure

① Copy the table on the previous page into your notebook.

② Set up your first series circuit (with one bulb) as shown in the diagram.

③ Close the switch and **record** your observations about the brightness of the bulb and the electric current flowing through the circuit.

④ Repeat steps 2 and 3 with two bulbs and then with three.

⑤ While all three bulbs are lit, unscrew one of the bulbs and **record** your observations in your table.

Analyze

1. How does the brightness of the bulbs change as more bulbs are added to the series circuit? How did the electric current as measured by the ammeter change?

Conclude and Apply

2. Using your results, explain why the brightness of the bulbs changes. Hint: use your knowledge of Ohm's Law and resistance to answer the question.
3. What happened to the series circuit when one of the bulbs was unscrewed? Using your knowledge of electric circuits, explain why this happened.

Extension

4. Predict what would happen if you continued to add more bulbs to the series circuit. Explain your answer.
5. Think of an example of a real-life circuit that behaves in the same way as the circuit you have just constructed.
6. Based on your observations, describe two advantages and two disadvantages to using this type of circuit.

Part B: Parallel

Procedure

① Copy the table on the previous page into your notebook.

② Set up your first parallel circuit (with two bulbs) as shown in the diagram.

③ Close the switch and **record** your observations about the brightness of the bulbs and the electric current flowing through the circuit.

④ Repeat steps 2 and 3 with three bulbs.

⑤ While all three bulbs are lit, unscrew one of the bulbs and **record** your observations in your table.

Analyze

1. How does the brightness of the bulbs change as more bulbs are added to the parallel circuit? How did the electric current as measured by the ammeter change?

Conclude and Apply

2. Using your results from the activity, explain any changes or lack of changes in the brightness of the bulbs.
3. What happened when one of the bulbs was unscrewed? Using your knowledge of electric circuits, explain why this happened.

Extension

4. Predict what would happen if you continued to add more bulbs to the parallel circuit. Explain your answer.
5. Think of and describe an example of a real-life circuit that behaves in the same way as the circuit you have just constructed.
6. Based on your observations describe two advantages and two disadvantages to using this type of circuit.

House Wiring

Practical electric circuits for the home are parallel circuits. The voltage across each load in a parallel circuit is the same. Turning on one appliance will not reduce the energy available to other loads. Plugging in an electric kettle, for example, will not cause lights on the same circuit to dim.

One potential problem does exist with parallel circuits. Current through wires connected to the source increases whenever another branch in the circuit is closed. When you turn on any appliance in your home, the current in the wires closest to the source increases. More current means the temperature of the conducting wires rises. If you turn on too many appliances at the same time and the current increases too much, the wires could become hot enough to start a fire. To guard against an electrical fire, household circuits always include fuses or circuit breakers (see Topic 7).

Pause& Reflect

Make a chart in your Science Log that summarizes the characteristics of series and parallel circuits. Make two columns, one with the heading "Series Circuits" and the other with the heading "Parallel Circuits." Under each heading, write a summary of the important facts about each type of circuit. Leave room for additional information.

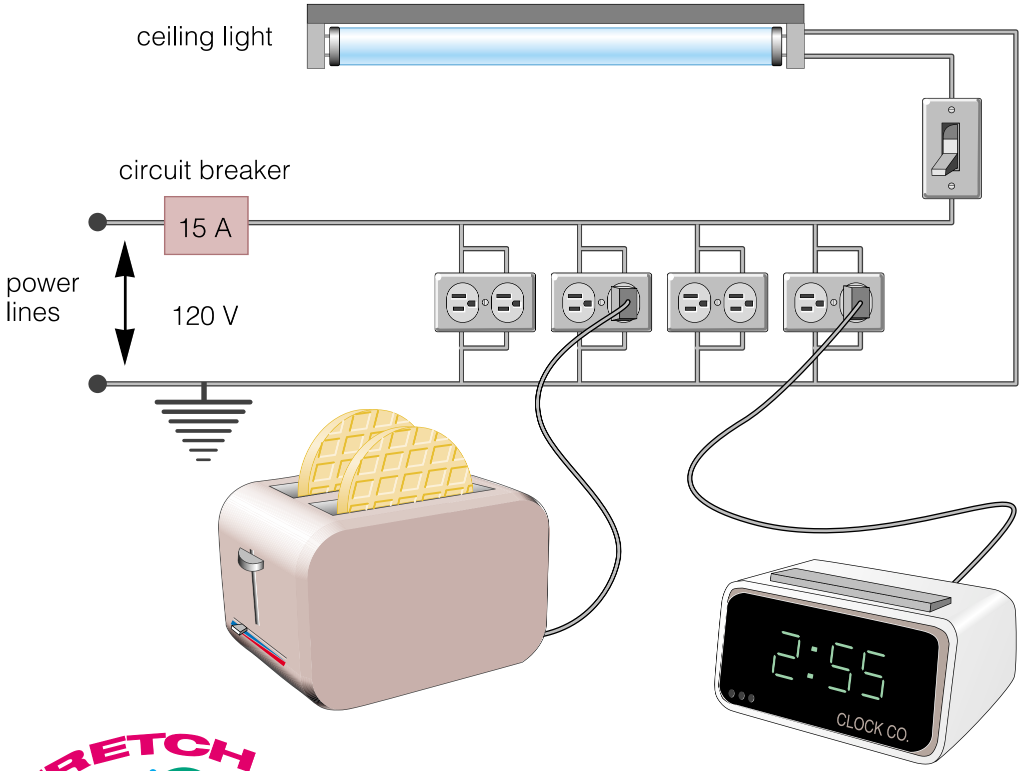


Figure 4.21 Household wiring connects appliances and lights in parallel along each branch circuit.

STRETCH Your Mind

In the series-wired circuits you have constructed in class, if one bulb burns out none of the others will light. In the early days of decorative lighting people had to remove and test each bulb in order to find the one that had burned out, a frustrating task indeed. Modern strings of lights are wired so that if one bulb burns out, the others keep operating. There are two common ways in which this problem has been solved. Can you describe both possible solutions?

PROBLEM-SOLVING

INVESTIGATION 4-D

Is Resistance Futile?

Can you design a simple electric circuit which allows you to dim a light or to turn off one light while leaving others operating? In this investigation you will use your knowledge of circuits and resistors to control electric current in specific, useful ways.

Challenge

Design and construct five separate circuits, each having *one* of the following characteristics.

(a) one bulb can be turned off while the other stays lit
(b) both bulbs can be turned off at the same time
(c) maximum current flows
(d) minimum current flows
(e) one light can be dimmed without affecting the brightness of the other light

Each circuit must use two light bulbs and any other necessary apparatus from the list below.

Apparatus

2 3.7 V bulbs
milliammeter
2 D-cells and holders
1 knife or button switch
2 bulb receptacles
1 m of Nichrome™ wire
1 m of copper wire
1 paper toilet paper roll
1 lead pencil
3 resistors (of various resistance)
6–8 wires with alligator clips

Safety Precautions

Design Specifications

A. Only the materials supplied by the teacher can be used to construct your circuit. You are not required to use *all* materials.

B. Each circuit must meet one of the design challenges.

C. Circuit components may not be added or removed during the operation of your circuit.

Plan and Construct

① With your group, brainstorm possible designs for each of the five required circuits. Choose one design for each circuit to construct and test.

② Use correct symbols to draw your five proposed circuit designs. Indicate which challenge each circuit is designed to meet.

③ After receiving teacher approval, construct and test each circuit in turn. Adjust your design until each circuit meets its challenge and also satisfies the general design specifications.

Evaluate

1. Demonstrate the operation of each circuit as directed by your teacher. Describe which types of circuits you constructed (series, parallel,or a combination) and explain why your designs enabled (or did not enable) your circuit to meet its challange.

2. Prepare a revised diagram of any circuit which was changed from its original design. Explain the specific problem which the changes overcame.

3. Label each circuit diagram to show whether the lights were connected in series or in parallel.

4. What energy transformation occurred when current passed through each component listed?

(a) the Nichrome™ wire
(b) the light bulbs
(c) the resistors

5. Describe at least three practical applications for a circuit that has variable resistance.

6. When the bulb in your circuit is being dimmed, where does the "lost" energy go? Could this cause any problems for the designers of variable resistors? Explain your answer.

Even good conductors like copper wires oppose the flow of electric charge. Table 4.7 shows how the actual resistance of a wire depends upon physical properties such as its cross sectional area ("thickness"), which is commonly described by an American Wire Gauge (AWG) number. Thicker wires (larger cross-sectional area) have *lower* resistance for a given length. For example, heavy-duty appliance wiring (#12 AWG) has a relatively large diameter, giving it lower resistance and the ability to carry higher currents without overheating than thinner light-duty extension cords (#16 AWG).

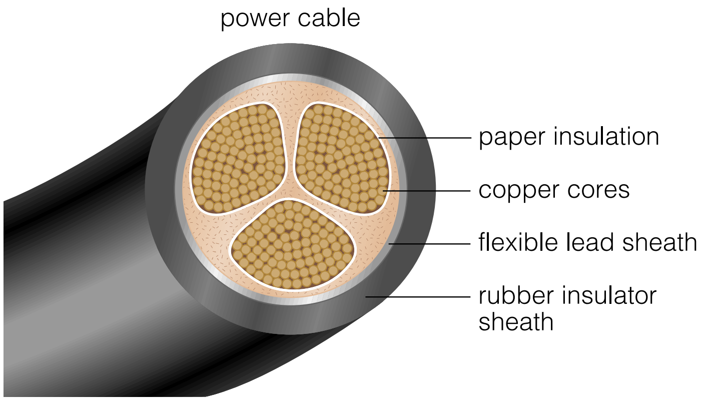


Figure 4.22 Power cables are made of many thin copper strands, which act together like one large-diameter conductor. This reduces resistance and heating and makes the cable more flexible.

Table 4.7 Factors Affecting Resistance of Wire

Factor	Effect
Length	Resistance *increases* with length. If the length doubles, the resistance doubles.
Cross-sectional Area	Resistance *decreases* with area. If the cross-sectional area doubles, the resistance is half as great.
Temperature	As the temperature of the wire increases, the resistance *increases*.
Material	Due to the structure of their atoms, some metals allow electrons to move more freely than others.

TOPIC 3 Review

1. In your own words, explain the meaning of electrical resistance.
2. What combination of units is equivalent to the ohm?
3. State Ohm's Law, and give the standard units for each quantity in it.
4. Explain the differences between a series circuit and a parallel circuit.
5. List three characteristics of a wire that affect its electrical resistance.
6. Which type of circuit, series or parallel, will produce the highest current through three bulbs? Give a reason for your answer.
7. **Apply** What is the voltage across an electric water heater element that has a resistance of 32Ω when the current through it is 6.8 A?
8. **Thinking Critically** Matt says that if the resistance to a load becomes larger, the current through it becomes larger as well. Angela says that if the resistance of a load becomes larger, the current will decrease. Do you agree with Matt or Angela? Explain your answer.

Wrap-up TOPICS 1-3

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

electric circuit
charged
neutral
electric current
static electricity
unbalanced charges
Laws of Charges
insulators
conductors
semiconductors
superconductors
electrostatic discharge
grounding
battery
switch
resistor
loads
voltage
amperes
galvonometer
ammeter
potential difference
resistance
ohm
Ohm's Law
series circuit
parallel circuit

Reviewing Key Terms

Copy and complete the statements below in your notebook.

1. The behaviour between charged and uncharged particles is explained by the __________. (1)
2. The term that most accurately describes the electric condition that occurs when two different materials are rubbed together is __________. (1)
3. A __________ is a material with higher conductivity than insulators but lower conductivity than metals. (1)
4. Components within an electric circuit that convert electricity to other forms of energy are called __________. (2)
5. Electric pressure or difference in electric potential is called __________. (3)
6. The property of substance that hinders the motion of electric charges and converts electric energy into other forms of energy is __________. (3)
7. A circuit with only one path along which a current can flow is a __________. (3)
8. The relationship between voltage and electric current can be explained by __________. (3)

Understanding Key Concepts

9. Explain how electric charges are produced. (1)
10. Can electric charges travel only through wires? Explain your answer and give at least two supporting examples. (1)
11. Describe the kinds of observations that led to the formation of the Laws of Charges. (1)
12. Describe how a buildup of electric charges can be neutralized. Provide at least two examples. (1)
13. What conditions must exist in order for an electric current to flow? (2)
14. Sketch how to connect (a) a voltmeter, and (b) an ammeter into a circuit. (2)
15. Write Ohm's law in the form used to find (a) resistance, (b) current, and (c) potential difference. (3)
16. Sketch circuit diagrams which show three load resistors connected (a) in series, and (b) in parallel. List important facts about current and potential differences in each circuit below the diagram. (3)
17. Describe at least three ways in which the resistance within an electric circuit could be reduced. (3)

TOPIC 4

The Energy Connection

What does the word "energy" mean to you? One definition of energy is "the ability to do work." Does that definition seem to apply to electricity? Electric motors certainly use electric energy to do work on objects by moving them. Energy, however, has another important characteristic: it appears in many forms. Some electrical devices, such as light bulbs and stoves, are designed to change electric energy into other forms of energy, such as light and heat. Other technology is able to transform heat, light and energy of movement (kinetic energy) into electrical energy. In this Topic, you will investigate a variety of forms of energy, and discover how they can be converted directly into electricity, and how electricity can be converted directly into other forms of energy.

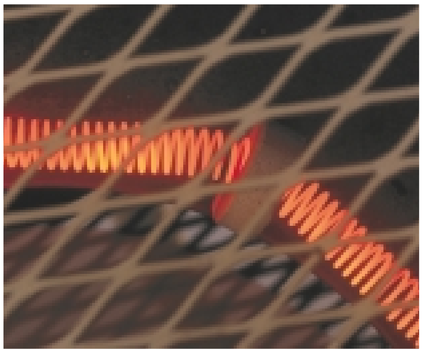


Figure 4.23 Heating elements convert electric energy into thermal energy. What other devices can you name that perform a similar energy conversion?

Find Out ACTIVITY

Something to Electricity: Electricity to Something

In your day-to-day life you encounter many devices that do useful tasks by converting electrical energy into some other form of energy. There are also many types of equipment that convert another form of energy into electricity.

Materials

reference materials (books, Internet, periodicals)
paper
pencil

Procedure

Analyzing and Interpreting

1. Copy the table at right into your notebook.
2. Think of familiar devices that convert electrical energy into some other form. Choose examples that cover a variety of forms of energy, and use them to fill in the table.
3. Choose one type of energy conversion and find out more about how it is achieved. Then choose a device that is designed to accomplish this conversion, and prepare a detailed explanation of how it works. Use a format specified by your teacher.
4. Present your findings about an energy-conversion device to the rest of the class. Discuss similarities and differences among the various conversion devices.

Device	Energy Conversion	
	Starting form	**Final form**
	electricity	
	electricity	
		electricity
		electricity

What Did You Find Out?

1. How does your list compare with that of your classmates? Add several more examples from their lists to your list.
2. Which type(s) of energy conversion occur most frequently in your list? Suggest a reason why this is so.

Word CONNECT

The movement of molecules within a substance produces thermal energy. *Heat* is defined as thermal energy that is transferred from a warmer substance to a cooler one.

Electricity and Heat

In appliances such as a stove or hair drier, electric energy is converted to heat as moving charges meet the resistance of a metal conductor. You observed this process in Find Out Activity: Resistance Roadblock in Topic 3. The opposite process is also possible.

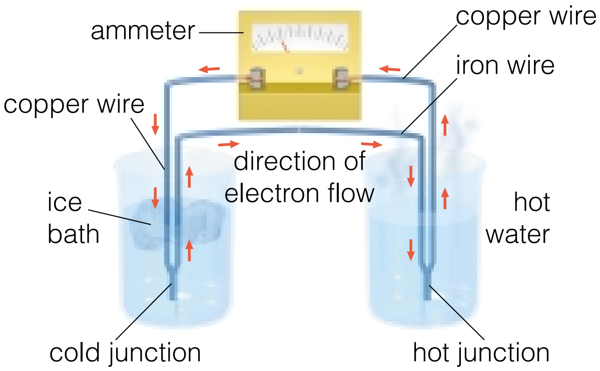
Heat can be converted directly to electric energy using a **thermocouple**. A thermocouple is a loop of two wires made of different types of metals. The wires are wrapped together at both ends, or "junctions." When one junction is heated, a small electric current is produced. If the temperature difference between the junctions is increased, the current increases. For example, one junction might be cooled while the other is heated. If the positions of the hot and cold junctions are reversed, current will flow in the opposite direction.

The basic principle of the thermocouple was discovered by Thomas Johann Seebeck in 1821, and was named the Seebeck Effect. Seebeck originally concluded that any two metals could be used. However, it is now known that not every combination of metals works in thermocouples. Copper and constantan (a copper nickel alloy), or iron and constantan, are the most common metals used in modern industrial thermocouples.

Individual thermocouples produce only a small amount of current. They are widely used to obtain accurate temperature measurements where regular liquid thermometers cannot be used.

DidYouKnow?

If you hook the two wires leading from a thermocouple to a battery, one junction will get hot and the other will get cold.



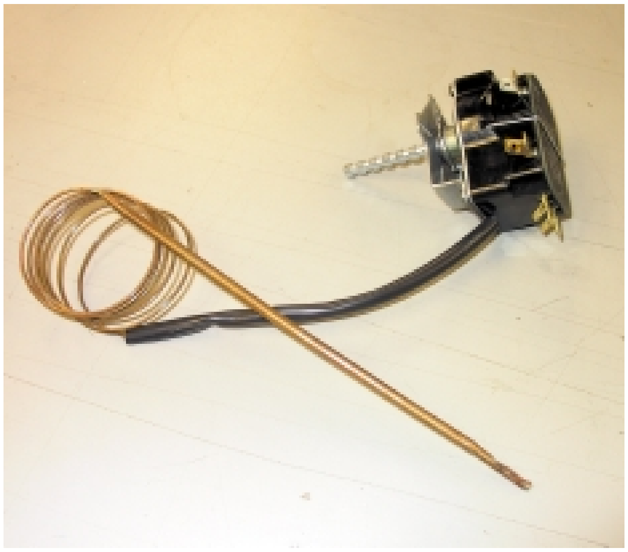


Figure 4.24 Thermocouples are rugged and can measure high temperatures. They are used as sensors in safety and control devices for furnaces, hot water heaters, and electric ovens.

A **thermo-electric generator** is a device based on a thermocouple that converts heat directly into electricity without moving parts. Heat from a gas burner or another heat source moves through several thermocouples connected in series — a *thermopile* — creating a potential difference. Thermopiles are extremely reliable, low-maintenance devices. They are used in remote locations to generate limited quantities of electrical energy that are sufficient to power, for example, emergency communications equipment.

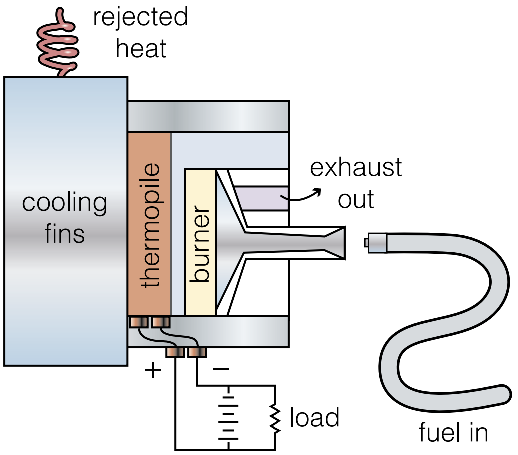


Figure 4.25 Thermo-electric generators such as this are manufactured by Global Thermoelectric, an industry-leading company based in Calgary.

On one side of the thermopile, a gas burner or other heat source is installed. The opposite side is kept cool by components such as aluminum cooling fins or heat pipe assemblies. Operating generators generally maintain temperatures of approximately 540°C on the hot side and 140°C on the cold side. The heat flow through the thermopile creates a steady flow of electricity. Individual thermo-electric generators can range in output size from 15–550 W and can be combined to produce up to 5000 W.

Electricity to Motion

How can sound be produced by tiny electric watches or the paper-thin sound modules in "talking" greeting cards? There is no room in these devices for even the smallest loudspeaker. Instead, sound is produced when an electric current causes vibrations in a tiny crystal — the piezoelectric effect. *Piezo* in Greek means pressure or push. When a piezoelectric crystal such as quartz or Rochelle salt is connected to a potential difference, the crystal expands or contracts slightly. Any material touching the crystal experiences pressure, which can create sound waves or vibrations. This link between electricity and pressure was first investigated in 1880 by two young French scientists, Pierre and Jacques Curie, who were 21 and 24 at the time.

Modern researchers have developed non-crystalline materials that move in response to an electric current. Such materials have many potential uses. For example, using a flexible polymer (plastic) with this property, Joseph Bar-Cohen, an American physicist, has created a robotic hand with four "fingers." When a voltage is applied, the plastic "fingers" bend, gripping any small object between them. Bar-Cohen's experimental device can lift only 10 g, the mass of a small ball point pen, but it is inexpensive, durable, and light.

Cool Tools

A scanning tunnelling microscope (STM) is one of the few machines capable of producing images of individual atoms. Parts of an STM must make incredibly small movements of only a few nanometres (10^{-9} m). The motion is produced by piezoelectric ceramic wafers, which move very slightly when a low voltage is applied to them.

Motion to Electricity

A barbecue "spark" lighter uses the piezoelectric effect in reverse. While a piezoelectric crystal is being compressed or pulled, a potential difference builds up on opposite sides of the crystal. Conductors attached to the crystal can connect it to a circuit, where the crystal acts as a source of electric energy. In a barbecue lighter, this creates a spark. Devices such as crystal microphones and some types of pressure sensors use the changing voltage from a piezoelectric crystal to control much larger electric currents in amplifiers and recording equipment.

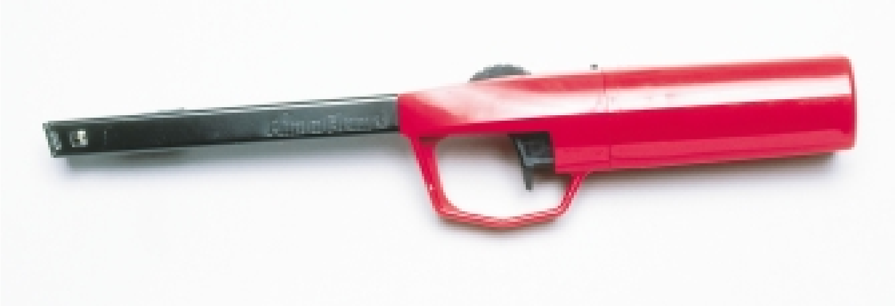
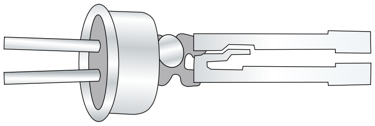


Figure 4.26 Squeezing the handle of a barbecue spark lighter slams a tiny hammer against a piezoelectric crystal, generating a potential difference of thousands of volts and a miniature lightning bolt across the spark gap.

DidYouKnow?

In 1927, Warren Morrison, a Canadian engineer working for Bell Laboratories in the United States, invented the quartz clock and revolutionized the way time was kept. The most common crystals are quartz crystals. Quartz is a piezoelectric material, and quartz crystals vibrate when a voltage from a battery is applied to them. Quartz watch crystals act as miniature tuning forks that vibrate 32 768 times per second. Other types of crystals vibrate at more than 50 million times per second.



Find Out ACTIVITY

Flashing Rocks

The piezoelectric effect produced by certain types of crystals can be observed as flashes of light as two crystals (rocks) are hit together. This activity allows you to experience piezoelectricity first hand.

Safety Precaution

Materials

2 large quartz (quartzite) crystals, preferably smooth and clear crystals or white quartzite pebbles
safety glasses or goggles
a very dark room or heavy blanket

Procedure ✷ Performing and Recording

1. Put on your safety glasses.
2. Select two pieces of quartz and either enter a darkened room or duck beneath a heavy blanket that does not allow light to penetrate.
3. Strike the two crystals together with a glancing blow.
4. Record your observations.

What Did You Find Out? ✷ Analyzing and Interpreting

1. What did you observe when the crystals were hit together?
2. Using your knowledge of piezoelectricity, attempt to explain your observations.
3. Describe a known application for what you have seen or invent an application of your own.

Electricity to Light

Using electricity to produce light seems like a pretty simple matter. In incandescent light bulbs, a filament made of a high-resistance metal glows brightly when an electric current passes through it. In fluorescent or neon bulbs, the electric current causes a gas or vapour to glow brightly. Piezoelectric crystals can produce light when they are hit together.

Some recent types of flashlights, bicycle lights, and toy lights do not have a light bulb. Instead they have light-emitting diodes (LEDs), solid-state electronic components that glow when electricity flows through them. LEDs use only a fraction of the power of a traditional bulb and last for years as opposed to months. How do they work? The heart of the LED is a tiny semiconductor chip that is often protected by a transparent plastic case. Unlike regular light bulbs, LEDs work only when connected to a circuit in one direction.

Figure 4.27 The plastic package of this light-emitting diode is about the size of a grain of rice, but all the light is produced from a microscopic area in the centre of the package.

Did You Know?

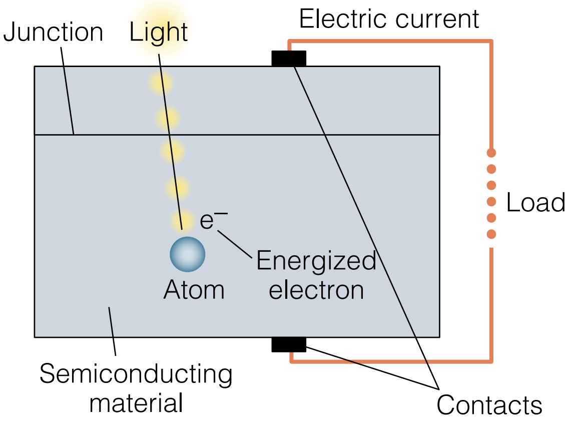
Thousands of miniature LEDs form the liquid-crystal and flat-panel displays used in many portable computers and hand-held "digital assistants." The displays use organic light-emitting liquids, which emit light when an electric current passes through them. The colour of light emitted depends on the particular type of material used. In order to observe the light emitted by an organic LED, at least one of the electrodes must be transparent.

Light to Electricity

As traditional methods of producing electricity are becoming more expensive and causing increased concerns about pollution, using light to produce electricity could play a large role in our future (see figure 4.28). The *International Space Station* is powered entirely by an electricity-generating solar array that will eventually cover an area of approximately 0.5 ha.

The device that is most commonly used to produce electricity from light is called a photovoltaic (PV) cell, or solar cell. Photovoltaic cells are made of semiconducting materials such as silicon. When light strikes the cell, some light is absorbed by the semiconductor material, breaking electrons loose and allowing them to flow freely. Metal contacts on the top and bottom of the PV cell allow this electric current to be drawn off for external use in devices such as calculators, water heaters, or emergency roadside telephones. Because voltage and current of an individual cell are limited, solar cells are usually combined to form modules, which are in turn combined to form arrays.

Figure 4.28 Light hitting an individual photovoltaic cell transfers energy to electrons, starting a current through the load. A rooftop solar array can power a house.



Find Out ACTIVITY

Show Me the Light!

How much electricity can be produced by photovoltaic cells (solar cells)? What factors affect the output of a photovoltaic cell? Investigate these questions as you perform this activity.

Materials

1–3 small photovoltaic cells
ammeter or milliameter
plug-in light source
wires with alligator clips
meter stick
protractor

Safety Precautions

If your light source uses an electric bulb, handle it carefully. Light bulbs are fragile and can get hot enough to burn you.

Initiating and Planning
Performing and Recording

Procedure

1. Work with your group to formulate a hypothesis that identifies one factor that you think affects the amount of current produced by a photovoltaic cell or cells. Predict how the current will change when this factor increases and decreases.
2. Design a simple investigation to test your hypothesis. Then carry out the investigation using the materials supplied.
3. Collect results from at least two other groups that investigated different factors.
4. Record your results and the results collected from your classmates in an appropriate format.

Analyzing and Interpreting

What Did You Find Out?

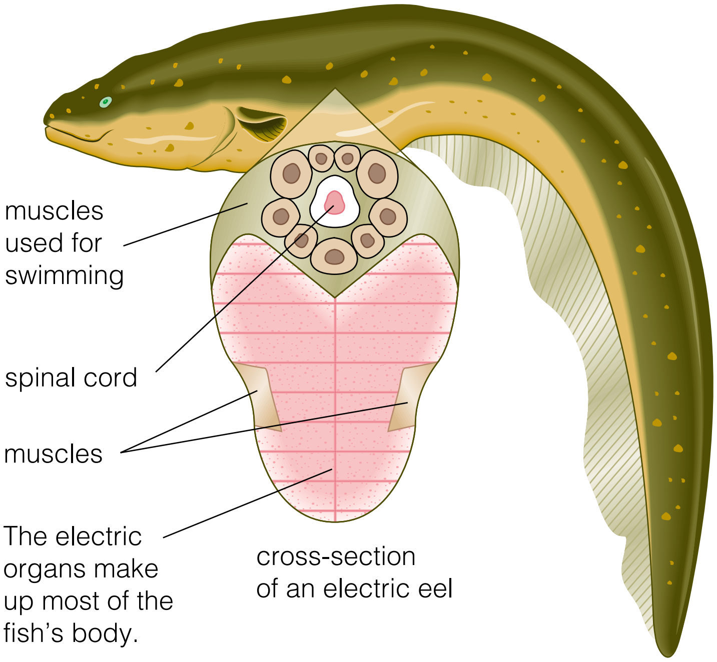
1. For the investigation carried out by your group, what were the manipulated and responding variables?
2. What were the manipulated variables in other groups' investigations?
3. Based on your findings, which variable or variables had the greatest effect on the electrical current produced by the cell? Suggest a reason why.
4. In addition to the factors investigated by groups in your class, name at least three other factors that might affect the ability of a photovoltaic cell to produce electricity.

Extension

5. Based on the data you collected, describe features you would include if you were to design a home powered by photovoltaic cells.
6. What are the main reasons why some people *are* currently choosing photovoltaics as a home power source, and the main reasons why other people *are not* using solar power?

DidYouKnow?

Many fish have electric organs that can produce a large voltage. They use this electric energy to detect enemies, navigate, and possibly to communicate. These animals are said to be electrogenic and electroreceptive. The South American fresh water eel, *Electrophorous electricus*, can generate the largest voltage of any fish. The electric organ consists of thousands of flat, specialized muscle cells, called electroplaques, which make up about 40% of the eel's mass. Each cell generates a voltage of about 0.15 V. Because the cells are connected in series, the electric organ can generate a total voltage of about 600 V. The eel releases a burst of electric energy, lasting about 3/1000 of a second, to stun prey. This "electric shock" causes the prey to stop breathing and drown. Then the eel consumes its meal.


muscles used for swimming
spinal cord
muscles
The electric organs make up most of the fish's body.
cross-section of an electric eel

TOPIC 4 Review

1. Describe at least three ways in which usable light can be produced from electricity.
2. How does a thermocouple work? Give two examples of uses for thermocouples.
3. What happens to a piezoelectric crystal when it is squeezed? Give one example of how this phenomenon can be applied.
4. What would happen if an electric current were passed through a piezoelectric crystal? Describe an application for this phenomenon.
5. Photovoltaic cells produce electricity from light. Describe two concerns or problems a homeowner might face in a house powered entirely by photovoltaics.

TOPIC 5

Portable Power

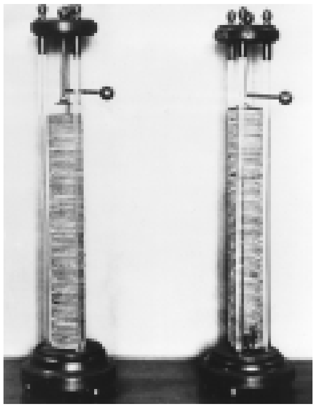


Figure 4.29 "Voltaic piles" like these, invented in 1800, were the first electric batteries.

How many battery-powered devices are in your household? How many batteries do you buy each year in order to transform chemical energy directly into electricity? Worldwide, people buy over 15 *billion* batteries annually. Luigi Galvani (1737-1798), who noticed that a frog's muscle would twitch when touched by two different metals, could hardly have imagined this outcome of his observations.

Galvani believed that the frog's tissues had a unique ability to generate "animal electricity." Later, Alessandro Volta (1745–1827) showed that a voltage could be generated without using living tissue by placing different metals in a solution containing a salt or acid. Today, such a device is called an **electrochemical cell**. You may recall from Topic 2 that a battery is just a series of connected cells.

Find Out ACTIVITY

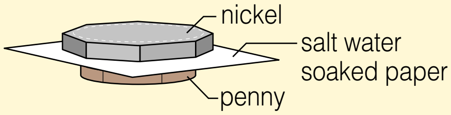
Pile of Power

Volta invented a battery composed of alternating layers of zinc, blotting paper soaked in salt water, and silver. In this activity, you will recreate Volta's design using common materials.

Materials

pennies, nickels, dimes
other coins
copper wires with alligator clips
voltmeter
scissors
paper towels
saturated salt water solution

Safety Precautions



Procedure

Performing and Recording

1. Cut circles about the size of a nickel out of the paper towel and soak them in the salt solution.
2. Construct a single cell as shown in the diagram.
3. Press wires from the voltmeter to the top and bottom coins in the pile. Record the voltage produced.
4. Add another penny and nickel layer to form a two-cell battery. Record the voltage produced.
5. Repeat steps 3 and 4 using more cells, a different arrangement of cell components, or a different combination of coins.

What Did You Find Out?

1. What components and conditions are essential for a cell to operate?
2. Based on your findings, what factors affected the voltage of your battery most?
3. Suggest at least three things you could do to make your battery produce even higher voltages.

Electrochemical Cells

In any electrochemical cell, two metal **electrodes** are surrounded by an **electrolyte**, a substance that can conduct electricity. "Wet cells" use a liquid electrolyte. Car batteries contain several wet cells. "Dry cells," such as those pictured in Figure 4.31, have a paste, plastic, or ceramic solid electrolyte.

Figure 4.30 shows the arrangement of parts in a typical aluminum-copper wet cell, as it could be set up in a laboratory. When the cell supplies current to a circuit, atoms of aluminum become ions and go into the electrolyte solution. As a result, the aluminum strip slowly disintegrates. A similar process occurs in every electrochemical cell: one electrode is consumed as the cell operates. Common "dry cells" sometimes leak when their zinc case, which forms one electrode, is eaten away and the electrolyte paste oozes out of the cell.

The chemical reactions in a cell determine the potential difference (voltage) that the cell can create. Very few single cells can produce more than 2 V. To obtain higher voltages, batteries contain several cells connected in series (Figure 4.31). If a cell cannot be recharged (a **primary cell**), the amount of chemicals it contains determines the total amount of electric energy the cell can produce. A large "D" cell, for example, contains more chemicals than a small "AA" cell, so the "D" cell has a longer working lifetime than an "AA" cell in an identical circuit. Rechargeable **secondary** cells use chemical reactions which can be reversed. In a recharger, electricity is forced through the "dead" cell, rebuilding the original chemicals and allowing the cell to be reused.

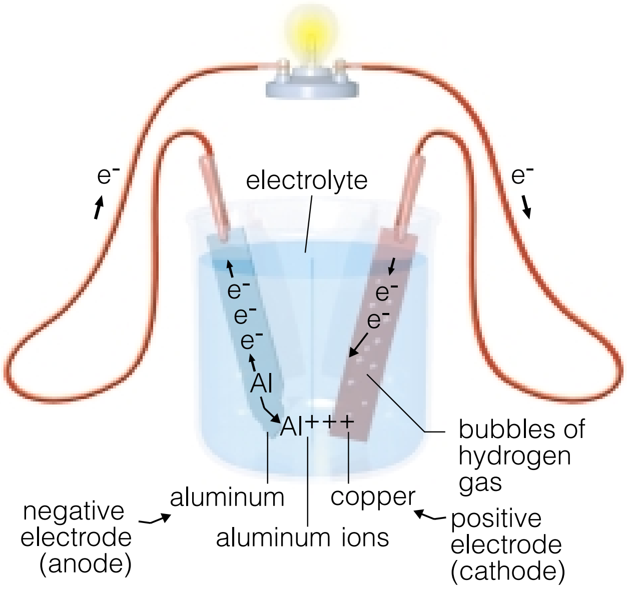


Figure 4.30 Copper and aluminum metal strips are submerged in an acid solution. As electrons move from the aluminum strip to the copper strip through the conducting wire, they light up the light bulb. The circuit is completed by the movement of charged metal ions in the electrolyte.

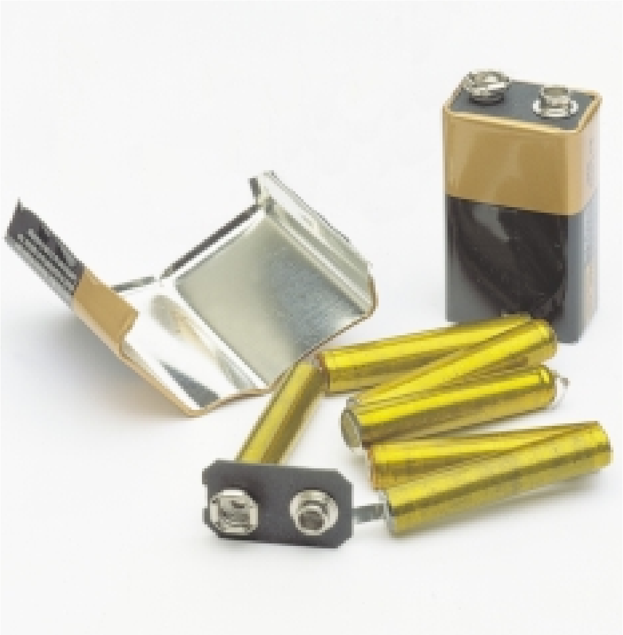


Figure 4.31 A 9 V battery contains six small 1.5 V cells. Are they connected in series or in parallel?

INQUIRY

INVESTIGATION 4-E

SKILLCHECK

- Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Super Cell Sleuth

In this investigation, you will study several variations of voltaic cells. You will discover factors that enhance or reduce the usefulness of the cells.

Question

What factors affect the voltage and current from a voltaic cell?

Hypothesis

Formulate a hypothesis about which factors you think will affect the voltage and current produced by a voltaic cell.

Safety Precautions

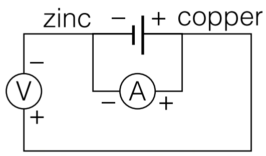
- When handling the metal strips that have been in acid, wear protective gloves and use absorbent paper.
- Inform your teacher if you know you are allergic to latex.
- Sulfuric acid is corrosive. Use only dilute sulfuric acid. If you get acid on your skin or clothing, rinse the area(s) immediately with large quantities of water. Call your teacher at once.

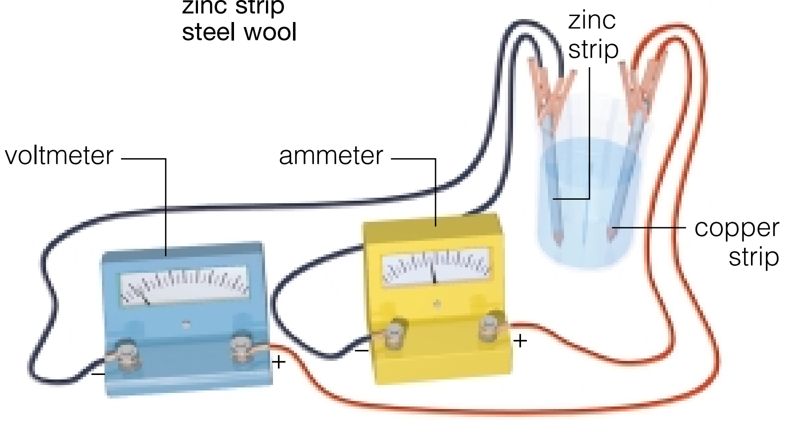
Materials

latex gloves
dilute sulfuric acid
distilled water
paper towel
salt solution
tap water

Apparatus

0–5 V voltmeter
0–1 A ammeter
beaker or battery jar
4 conducting wires
aluminum strip
2 copper strips
zinc strip
steel wool





Procedure

① Make a table as shown below.

② Polish both sides of the metal strips with steel wool.

③ Fill the beaker two-thirds full with dilute sulfuric acid.

Factors Affecting a Voltaic Cell

Factor changed	Metal strips	Solution	Current (A)	Voltage (V)	Action at strips
Initial reading	copper and zinc	sulfuric acid			
After running for 5 min	copper and zinc	sulfuric acid			
Wipe bubbles off	copper and zinc	sulfuric acid			
Change surface area of metals in solution	copper and zinc	sulfuric acid			
Use one new metal strip	aluminum and zinc	sulfuric acid			
Use identical strips	copper and copper	sulfuric acid			
Change solution to water	copper and zinc	distilled water			

④ With separate conducting wires, connect the zinc strip to the negative terminal of the voltmeter and the ammeter. Connect the copper strip to the positive terminals of the voltmeter and the ammeter.

⑤ Check with your teacher to make sure your circuit is wired correctly. Then *carefully* lower the zinc and copper electrodes into the acid solution. Do not let the electrodes or clips on the connecting wires touch.

⑥ Read and **record** the values for current and potential difference. Note and **record** whether bubbles form on either metal strip.

⑦ Allow the cell to operate for about 5 min. Watch for the formation of bubbles on the surface of the metal strips. **Record** whether there are more bubbles on the zinc or on the copper strip.

⑧ Read the meters after the cell has been running for 5 min. **Record** the results.

⑨ Wearing protective gloves, carefully lift the strips from the solution. Wipe away any bubbles from the metal with paper towel. Put the strips back in the acid solution and repeat step 6.

⑩ Once again, wipe away any bubbles from the metal strips. Raise the metal strips so that only half of the length is still in the dilute sulfuric acid. Repeat step 6.

⑪ Remove the copper strip and replace it with an aluminum strip. Repeat step 6.

⑫ Remove both the zinc and aluminum strips and replace them with two copper strips. Repeat step 6.

⑬ Rinse the metal strips with tap water and replace the solution in the voltaic cell with the distilled water. Replace one copper strip with a zinc strip. Repeat step 6.

⑭ Carefully dispose of used paper towel and acid, and clean up acid spills according to your teacher's direction.

⑮ Clean all surfaces and wash your hands thoroughly.

Analyze

1. What variables did you manipulate in this investigation?
2. What was the responding variable in this investigation?
3. What evidence did you observe on the surface of the copper strip to indicate that a chemical reaction was taking place?
4. What happened to the electric current and electric potential difference as time passed?
5. What effect did each of the following actions have on the **(a)** potential difference; **(b)** the current?
   - Removing the bubbles from the surface of the metal
   - Changing the surface area of the metal strips in the solution
   - Using aluminum and zinc instead of copper and zinc
   - Using identical metals
6. Which factors appear to **(a)** determine the potential difference; **(b)** increase the current?
8. Using the copper and zinc strips, which combination of factors produced the largest current?
9. Which pair of metals produced the largest potential difference: copper and zinc or aluminum and zinc?
10. If you were designing a voltaic cell, which combination of metals and conditions would you use? Why?

Extension

11. Will the voltaic cell still work if the sulfuric acid is replaced with a concentrated salt water solution? Explain. If time permits, ask your teacher for permission to test your prediction.

Types of Cells

Examine the diagrams below and Table 4.8 to find out more about common types of cells.

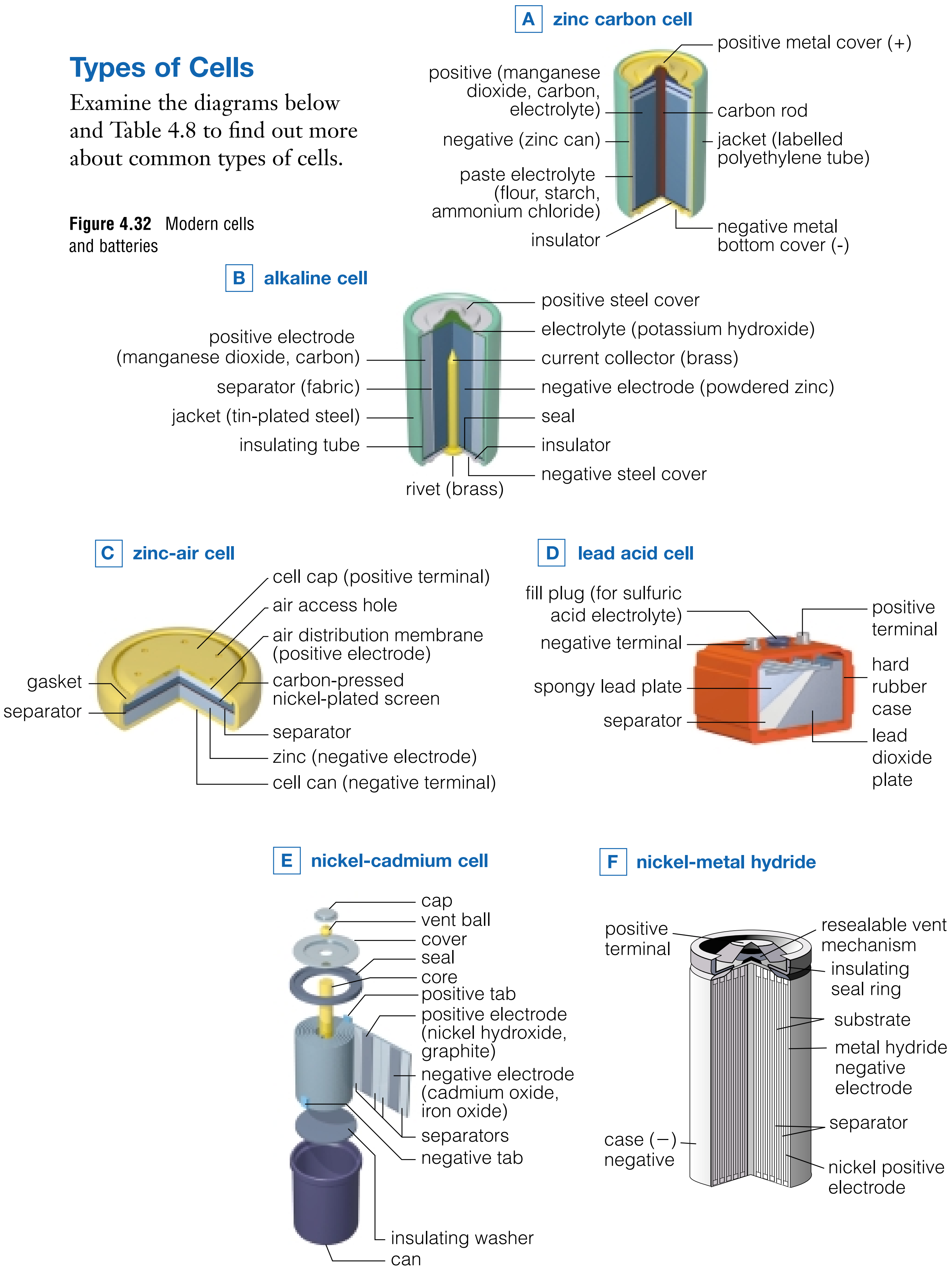


Figure 4.32 Modern cells and batteries

A
zinc carbon cell
positive metal cover (+)
positive (manganese dioxide, carbon, electrolyte)
carbon rod
negative (zinc can)
jacket (labelled polyethylene tube)
paste electrolyte (flour, starch, ammonium chloride)
insulator
negative metal bottom cover (-)
B
alkaline cell
positive steel cover
electrolyte (potassium hydroxide)
positive electrode (manganese dioxide, carbon)
current collector (brass)
separator (fabric)
negative electrode (powdered zinc)
jacket (tin-plated steel)
seal
insulating tube
insulator
negative steel cover
rivet (brass)
C
zinc-air cell
cell cap (positive terminal)
air access hole
air distribution membrane (positive electrode)
gasket
carbon-pressed nickel-plated screen
separator
separator
zinc (negative electrode)
cell can (negative terminal)
D
lead acid cell
fill plug (for sulfuric acid electrolyte)
positive terminal
negative terminal
hard rubber case
spongy lead plate
separator
lead dioxide plate
E
nickel-cadmium cell
cap
vent ball
cover
seal
core
positive tab
positive electrode (nickel hydroxide, graphite)
negative electrode (cadmium oxide, iron oxide)
separators
negative tab
insulating washer
can
F
nickel-metal hydride
positive terminal
resealable vent mechanism
insulating seal ring
substrate
metal hydride negative electrode
separator
case (−) negative
nickel positive electrode

Table 4.7 Commonly Used Cells and Batteries

Name	Primary/ secondary	Dry/wet	Positive electrode	Negative electrode	Electrolyte	Typical uses	Pros and cons
zinc carbon	primary	dry	manganese dioxide and carbon	zinc	flour, starch, and ammonium chloride	flashlights, portable radios, CD players	not efficient at low temperatures
alkaline	primary	dry	see diagrams	see diagrams	see diagrams	flashlights, portable radios, CD players	last longer than zinc carbon, expensive
zinc air	primary	dry	see diagrams	see diagrams	potassium hydroxide	calculators, hearing aids, watches	highest energy per unit mass, discharges rapidly
lead acid	secondary	wet	see diagrams	see diagrams	see diagrams	cars, motorbikes, snowmobiles, golf carts	dependable, heavy, corrosive liquid
nickel cadmium	secondary	dry	see diagrams	see diagrams	potassium hydroxide	electric shavers, laptop computers, power tools, portable TVs	rechargeable hundreds of times
nickel-metal hydride	secondary	dry	see diagrams	see diagrams	potassium hydroxide	cameras, laptops, cell phones, hand tools, toys	less toxic than NiCad, 40% more energy density than NiCad, rechargeable, no memory effect, lose charge when stored

Find Out ACTIVITY

Select a Cell

Each type of cell has characteristics that suit it to particular uses. You would not use car batteries, for example, to power a portable stereo. Can you choose cells which best suit different applications?

Procedure

Analyzing and Interpreting

1. Make a table with three headings: *application*, *cell features*, and *best cell types*.
2. Decide on desirable features of a cell for each application listed at right.
3. Using information from Table 4.7 and from other reference sources, select the most appropriate type of cell for each use.

Applications

laptop computer
electronic wristwatch
emergency warning light
child's toy robot
cave explorer's headlamp
rechargeable flashlight
high-powered camcorder light
hearing aid
emergency locator beacon
digital camera

What Did You Find Out?

1. Which type of cell appeared most frequently in your chart?
2. Which type(s) of cells do you use most frequently? For which applications?
3. What other types of electrochemical cells do you know of in addition to the ones described on these two pages?

PROBLEM-SOLVING

INVESTIGATION 4-F

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Building a Battery

Now that you understand how a battery operates, use your knowledge to create a battery using several dry cells in different combinations. Connect dry cells in several different arrangements.

Challenge

Assemble and test different combinations of individual dry cells to create a battery that will light a bulb most brightly.

Design Specifications

A. All batteries must use two or three individual cells.

B. The dry cells can be placed in series or in parallel or both.

C. The results of your tests should be recorded in a table such as the one below. For each trial, draw a diagram using the proper number and arrangement of cell symbols to show how the battery was constructed.

Safety Precaution

Cells in Series and in Parallel	Voltage (V)	Brightness of bulb (same, brighter, dimmer)
One cell		standard for comparison
Two cells in series		
Three cells in series		
Two cells in parallel		
Three cells in parallel		
Series batteries with one cell reversed		

Plan and Construct

① With your group, predict which arrangement of cells will produce the most powerful battery.

② Lay out the circuit illustrated below. Make sure the positive (red) terminal of the voltmeter is connected to the positive terminal of your battery.

③ Measure and record the voltage across the dry cells.

Evaluate

1. Which of your batteries lit the bulb most brightly?

2. Is there any relationship between the voltage of the battery and the brightness of the bulb? If there is, write a statement describing the relationship.

3. Write a statement that describes any advantage gained by putting two or more cells

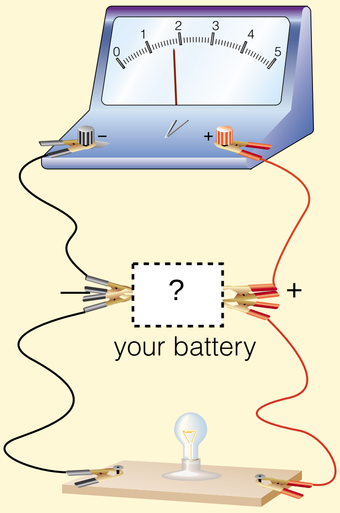
   (a) in series with each other

   (b) in parallel with each other

   (Be sure to include information about voltage and current in your answers.)

4. How did you reach your conclusions about current when you did not use an ammeter?

5. Explain what happened when the three cells were connected with the third in a direction opposite from the first two.



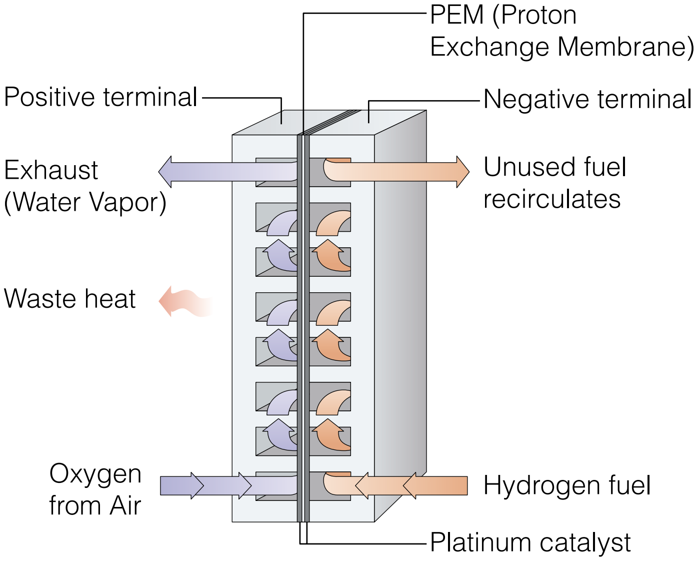
Across Canada

Automobile companies are investing millions of dollars to develop electric vehicles powered by fuel cells, instead of traditional batteries. Ballard Power Systems, in Burnaby, B.C., is a world leader in fuel cell technology. The company was established in 1979 to research and develop high-energy lithium batteries. By 1983, Ballard's engineers were developing, manufacturing, and marketing proton exchange membrane (PEM) fuel cells. Today, the company is working with other world leaders in fuel cell technology to create products for the mass market.

Ballard Power System's technology allows the production of efficient, environmentally friendly power sources for automobiles, electric equipment, and portable power production. This company's fuel cells boast zero emissions of harmful chemicals. To create electricity, Ballard's fuel cells combine hydrogen and oxygen without combustion. Electricity, heat, and pure water are the only by-products of the fuel cell's reaction. Unlike other electrochemical cells, fuel cells are not limited by the supply of chemicals inside them. As long as the proper fuel is supplied, the cell continues to produce electricity.

Another benefit of fuel cells is their efficiency. Proton-exchange membrane fuel cells are 50–85% efficient. Traditional automobile engines are only 25–40% efficient and emit harmful pollutants into the atmosphere.

Ballard Power Systems, along with international companies including DaimlerChrysler, Ford, GPU International, and ALSTROM, are working together to make Ballard fuel cells more readily available. Developing an efficient, inexpensive, and non-polluting source of hydrogen fuel for the cells is one focus of current research.



TOPIC 5 Review

1. What are the main components in a voltaic cell? Describe the function of each component.
2. How do batteries differ from cells? What arrangement of three cells will result in the greatest electric current? Which arrangement would result in the greatest longevity for the battery?
3. Describe three factors within a voltaic cell that you could manipulate in order to produce a cell with the highest possible voltage. For each factor describe how you would manipulate it.
4. Explain the difference between
   (a) wet cells and dry cells
   (b) primary and secondary cells
5. Describe the advantages and disadvantages of using fuel cells compared to other types of electrochemical cells.

Wrap-up TOPICS 4-5

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

electric energy
heat
thermocouple
thermo-electric generator
thermopile
piezoelectric effect
photovoltaic cell (PV)
electrodes
electrolyte
fuel cell

Reviewing Key Terms

1. In your notebook, write the key term that best matches each of the following words or phrases.

(a) a form of energy that is always transferred from a warmer substance to a cooler one (4)

(b) device that converts heat to a small amount of electric energy often used in temperature sensors. (4)

(c) a push-button barbeque lighter produces a small electric current (4)

(d) thermocouples combined to produce greater amounts of electricity (4)

(e) a device, usually composed of silicon, that can be used to produce electricity from light (4)

(f) different types of metals in a voltaic cell that have different attractions for electrons (5)

(g) a substance that can conduct an electric current through the movement of ions (5)

Understanding Key Concepts

2. Identify three devices that convert electrical energy into light, and give an advantage and disadvantage of each one. (4)

3. Copy the diagram of the thermocouple into your notebook. Add labels and arrows to show the key parts and movement of charge. (4)

4. Describe an advantage of thermocouples over regular liquid thermometers. (4)

5. Why are thermo-electric generators most often used in remote locations? (4)

6. What was Luigi Galvani's hypothesis about "animal electricity?" Did Volta's "pile" support that hypothesis? (5)

7. For each of the following voltaic cells, describe whether it would produce a voltage. Explain your reasons for each prediction. (5)

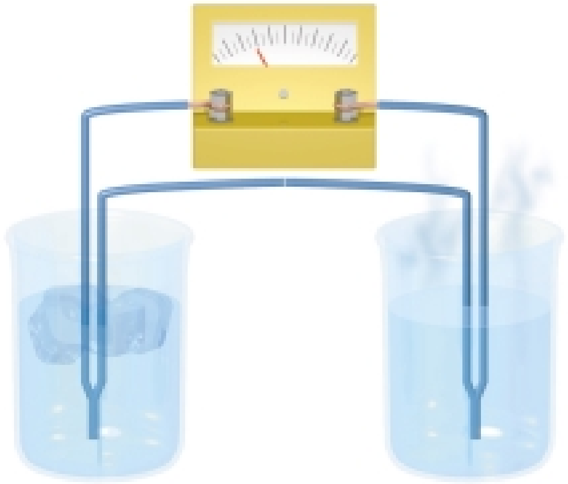
(a) a cell with copper and zinc electrodes in an acid electrolyte

(b) a cell with two copper electrodes in a salt water electrolyte.

(c) a cell with zinc and carbon electrodes in a distilled water electrolyte

8. If two D-cells are connected positive end to positive end, how much voltage would a voltmeter across the total array indicate? Give a reason for your response.(5)

9. Describe at least two possible benefits and two possible drawbacks of passing a law requiring that all new cars be powered by electricity generated by fuel cells. (5)



TOPIC 6 Generators and Motors

Imagine depending on battery-powered flashlights to light a sports field for a night game. Not likely? Batteries are fine for portable power, but they cannot supply the quantities of electricity required for outdoor lighting equipment, heavy appliances, and large industrial machinery.

Most of our electricity comes from the conversion of mechanical energy. Mechanical energy is associated with any system with moving parts — for example, a rotating windmill, spinning turbines in thermo-electric, nuclear, or geothermal power plants, or the moving water of rivers of tides. A device that converts mechanical energy into electric energy is called an **electric generator**. The operation of a generator depends on a relationship that surprised early scientists — electricity and magnetism are related.

Find Out ACTIVITY

Electric Current-Generating Tube

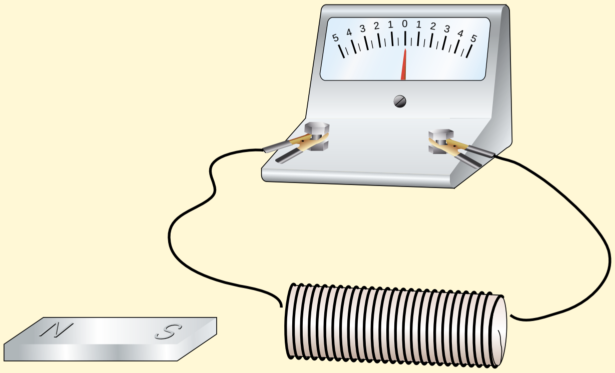
Using a magnet and a coil of wire to produce an electric current is the basic principle of electric generators. In this Activity you will have the opportunity to investigate factors that affect the current produced by a simple generator.

Materials

5 m of insulated copper wire (about 26 gauge)
cardboard tube
galvanometer or milliammeter
ammeter
powerful bar magnet

Procedure ✷ Performing and Recording

1. Leaving about 15 cm for a lead at the end of the wire, make a coil of about 25 turns by wrapping the wire around the cardboard tube. Remove the tube from the coil.
2. Strip the insulation off each end of the wire. Then connect the wire to the ammeter.
3. While closely monitoring the meter, insert one end of the bar magnet into the coil of wire and then pull it out. Record any movement of the meter needle that you observe.
4. Next, record the effect on the meter needle when you:
   - **(a)** vary the speed with which you move the magnet inside the coil of wire
   - **(b)** vary the speed with which you move the magnet over the outside of the coil
   - **(c)** move the coil over the magnet while the magnet remains still
   - **(d)** move the magnet ouside the coil in different directions



What Did You Find Out? ✷ Analyzing and Interpreting

1. How does the magnet's speed affect the current that is produced?
2. How does the position of the coil or magnet affect the current produced?
3. What combination of conditions generates the largest current?

Figure 4.33 Hans Christian Oersted (1777–1851) was a Danish physicist who wanted to show that there was no relationship between electricity and magnetism, but he observed just the opposite.

Electricity to Magnetism

The idea for the first electric generators dates back to a discovery by Hans Christian Oersted and André-Marie Ampère in 1820. They noticed a relationship between electricity and magnetism. Oersted observed that a compass needle turned when it was near a wire carrying electric current. The amount of deflection depended on how much electric current was flowing in the wire. When the direction of the current was reversed, the needle of the compass moved in the opposite direction. As soon as the current was interrupted, the magnetic effects ceased.

Electromagnets

When a soft iron core is inserted into a coil of wire and a current is passed through the wire, an even stronger temporary magnet called an **electromagnet** is created (see Figure 4.34). When electric current flows in the coil, one end of the core becomes a magnetic north pole and the other the south pole. When more coils of wire are wrapped around the iron core, the strength of the magnet increases. Increasing the current also results in a stronger magnet. If the direction of the current is reversed, the polarity of the magnet is also reversed. When the current is turned off, the iron core loses its magnetic properties.

The strength of an electromagnet depends greatly on its core material. Iron cores are much more effective than other metals, wood, or plastics at producing strong electromagnets.

Michael Faraday (1791–1867) is credited with discovering the basic principles of electromagnetism. Faraday became interested in chemistry and physics while reading science texts as he apprenticed as a bookbinder. At 21, he was accepted as a laboratory assistant to chemist Humphrey Davy. Faraday's experiments form the basis of modern electromagnetic technology and electrochemistry. He introduced terms such as "ion," "electrode," "cathode," and "anode" to science, and invented the idea of lines of magnetic force. The farad, the unit for stored electric charge, is named in his honour.

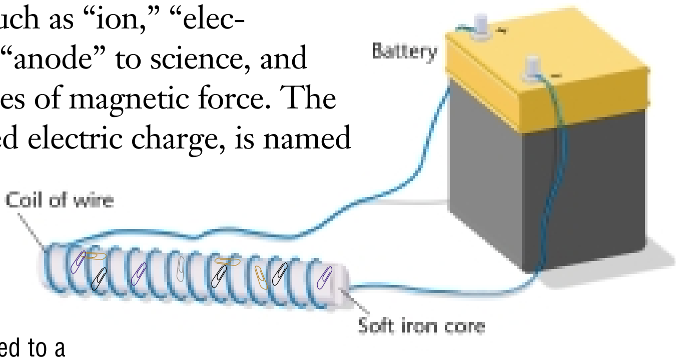
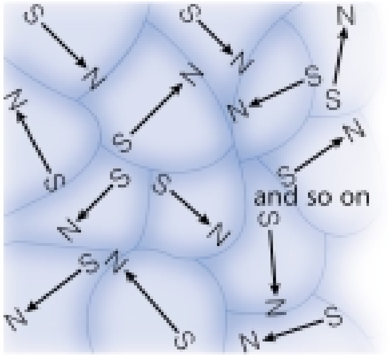
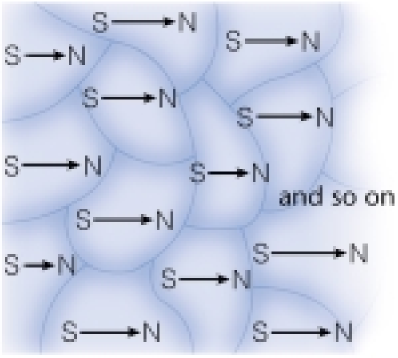


Figure 4.34 A simple electromagnet consists of an electric power source connected to a wire coiled around a soft iron bar.



unmagnetized material



magnetized material

DidYouKnow?

Individual atoms behave like tiny magnets, each having a north and south pole. Atoms in materials like iron, cobalt and nickel, group together into *magnetic domains*, in which all the north poles face the same way. Unmagnetized objects have domains that are randomly arranged. Their magnetic effects cancel out. Domains in a magnet or electromagnet, however, are aligned, so the resulting magnetic effects are strengthened. Magnetic domains in iron line up very easily, so iron is an effective core for electromagnets.

PROBLEM-SOLVING

INVESTIGATION 4-G

SKILLCHECK
- ✹ Initiating and Planning
- ✹ Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

The Attractive Electromagnet

Using the basic principles upon which electromagnets operate, you can produce surprisingly strong magnetic effects. In this investigation you will assemble and test a circuit that creates and controls a strong electromagnet.

Challenge

Using the materials supplied, design an electromagnet that will allow your group to transport the largest possible number of metal objects a specified distance in a fixed time.

Apparatus

5 cm iron nails
10 cm iron nails
paper clips
iron bolts and nuts
straight pins
1.0 m and 0.5 m lengths of insulated copper magnet wire, such as #26 AWG
D-cells (2 per group)

Safety Precautions

Design Specifications

A. The D-cells and wire may be used to construct one or two electromagnets.

B. You may use either a single 1.0 m length, or two 0.5 m lengths of magnet wire.

C. Your electromagnet(s) may be constructed from any or all of the supplied materials.

D. Each group will have 2 min to lift and transport as many metal objects as possible from a table, across a 4 m space, and into a collecting container, using only their electromagnet(s).

E. You may not touch the metal objects with your hands to help your electromagnet lift, transport, or drop them.

Plan and Construct

❶ With your group, plan and then construct your electromagnet.

❷ Plan how to use your electromagnet to pick up, transport, and drop metal objects. Test your strategy and modify it if necessary.

❸ Test your electromagnet as your teacher directs.

Evaluate

1. Calculate the total number of points your electromagnet earned during its trial.

Metal object	Point value
straight pin	2
paper clip	4
iron nut	8
iron bolt	12

2. How did you make your electromagnet as powerful as possible?

3. How did you release objects from the electromagnet? How effective was this method? How could it be improved?

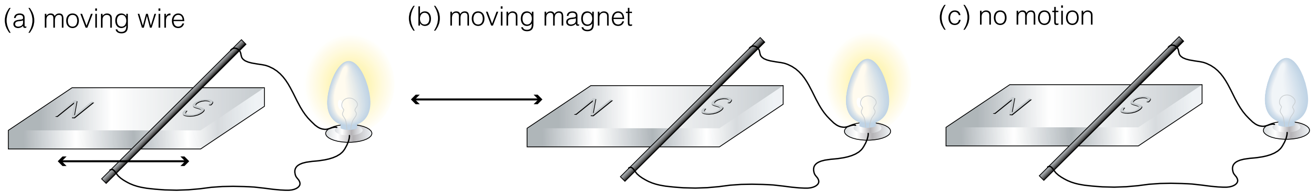
Extend Your Skills

4. If your school has computer probeware, develop and test an alternative way of measuring the strength of your electromagnet. You may wish to use a force probe or a magnetic field sensor.

Magnetism to Electricity

Experiments such as the one you have just done show that magnetic effects can be produced by electric currents. The opposite process is also possible. Electric effects can be produced using a magnet, as you observed at the beginning of this Topic. Michael Faraday and an American scientist named Joseph Henry made this discovery in 1831. Working independently, they found that a voltage developed in wires that were moved at an angle to a nearby magnet. The same thing happened when the magnet moved at an angle to a stationary wire. If the motion stopped, or if the magnet and wire moved parallel to each other, no voltage developed.

Faraday and Henry extended their experiments by connecting the wire to a load. Now an electric current flowed in the circuit, but only as long as either the wire, or the magnet, or both were moving (Figure 4. 35). Wrapping the wire into a coil around the magnet increased the current, as you have observed.


(a) moving wire

(b) moving magnet

(c) no motion

Figure 4.35 Relative motion between a wire and magnet causes a current to flow in a circuit connected to the wire.

Today, we say that a potential difference (voltage) is "induced" in a wire when there is relative motion between the wire and a nearby magnet. When the wire is connected to a circuit, an "induced current" flows. This connection between magnetism and electricity was used to develop motors, generators, and other electrical technology long before scientific theories were developed to explain the relationship.

Cool Tools

Current-carrying coils around this experimental Tokamak nuclear fusion chamber turn it into a gigantic electromagnet. Gas molecules with a temperature of more than 10 000 000°C are suspended and compressed by the magnetic effects.

Extremely powerful electromagnets have many other uses. Experimental maglev (magnetic levitation) trains use the repulsion between electromagnets on the train cars and electromagnets mounted between the tracks to suspend the entire train above the track, reducing friction and increasing efficiency.

In hospitals, patients are wheeled inside gigantic electromagnets in MRI (magnetic resonance imaging) equipment. As atoms in the patient's body are twisted by the powerful magnets, they emit radio signals that can be detected, analyzed, and assembled into images by computer. MRI equipment can produce detailed images of soft body tissues that cannot be examined using X rays.

What's in a Generator?

This AC generator, the most common form, has a coil of wire that rotates inside a stationary field magnet (see Figure 4.36). The coil is rotated by an external force, which is usually supplied by steam, falling water, or wind. Most large generators use electromagnets rather than permanent magnets.

As wires in the coil rotate, electrons begin to move along the wire in one direction. After one-half revolution of the wire loop, each side of the coil passes near the opposite pole of the magnet. The electrons in the coil start moving in the other direction. The direction of the current from the generator changes twice with each revolution. Electricity produced by this type of generator is called **alternating current** (AC) because it changes direction, or "alternates" (see Figure 4.37).

In North America, generators turn at a controlled speed, providing alternating current that changes direction 120 times per second. On a graph, the current has a wave shape, with 60 complete waves each second, so we describe it as 60 Hertz (60 Hz), or 60 cycle AC.

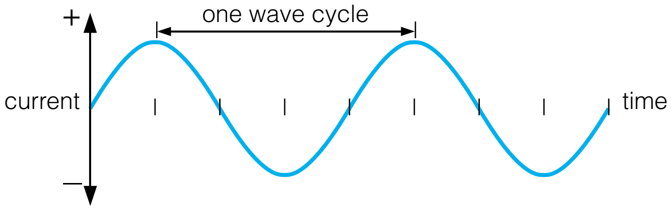


Figure 4.37 Current from an AC generator constantly varies in size and direction. Positive and negative values on the graph represent the opposite directions of the current flow.

Why do most power plants produce alternating current rather than direct current? One reason is that it is relatively easy to increase or decrease the voltage of alternating current. In order to travel long distances efficiently through transmission lines, the voltage is increased. For consumer use, voltage must then be decreased. This process involves transformers, which will be discussed in more detail in the next Topic.

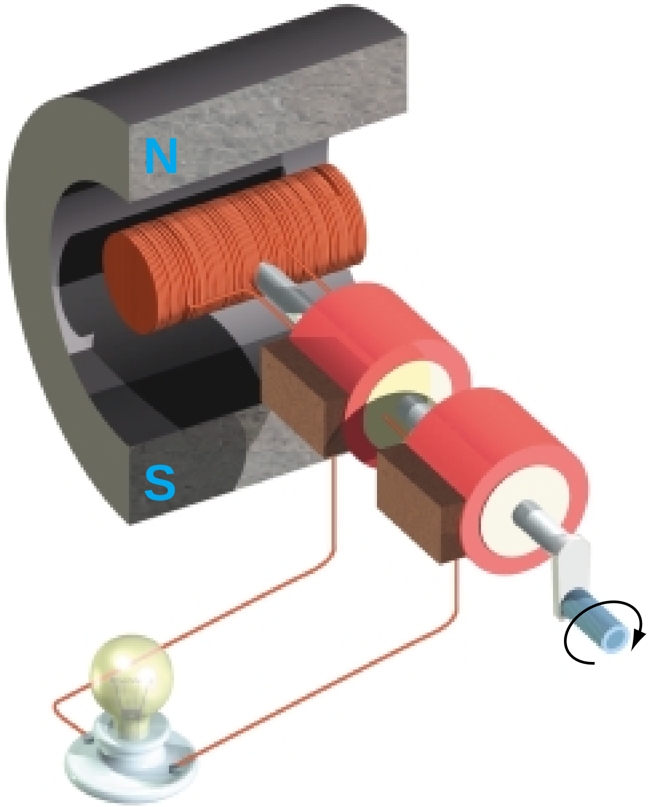


Figure 4.36 In this AC generator, electric current is produced when a coil of wire is rotated inside a magnet. (As you know, current can also be produced when a magnet is rotated within a coil of wire.) In this hand-cranked model, everything attached to the shaft rotates as a unit.

Word CONNECT

Generators that produce alternating current are also called *alternators*. Car electrical systems often use an alternator to generate AC, which is then converted to direct current for the motor's ignition system. Multiple choice tests present you with several *alternative* answers. A sports team may have practices and games on *alternate* nights. What is the common feature of words and phrases based on "alternate"?

DC Generators

Generators can also produce direct current (DC), or current in only one direction. A generator that produces direct current is often called a **dynamo**. In a dynamo, the armature (rotating loop of wire) is connected to the outside circuit by a split-ring **commutator** (Figure 4.38A).

To visualize how the commutator operates, study the four parts of Figure 4.38B. (The red dot on the armature lets you track its rotation.) In position 1 the brushes touch the metal split rings, so electrons flow from and return to the armature. When the armature and commutator rotate to position 2, insulating gaps in the commutator momentarily stop the electric current. As the gaps move past the brushes, current resumes (position 3). At this point, the direction of charge flow in the armature has reversed, but so has the connection through the commutator. As a result, current continues through the load in a constant direction. The same sequence of events repeats continuously as the armature keeps rotating past position 4.

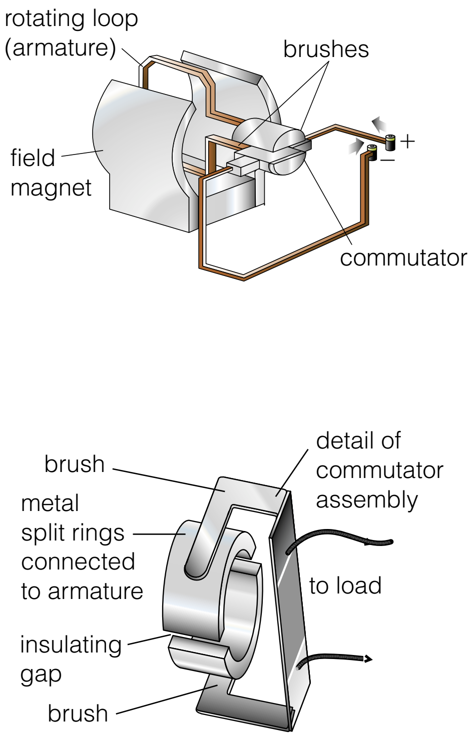


Figure 4.38A A typical DC generator has a split-ring commutator so it sends current through a circuit in only one direction.

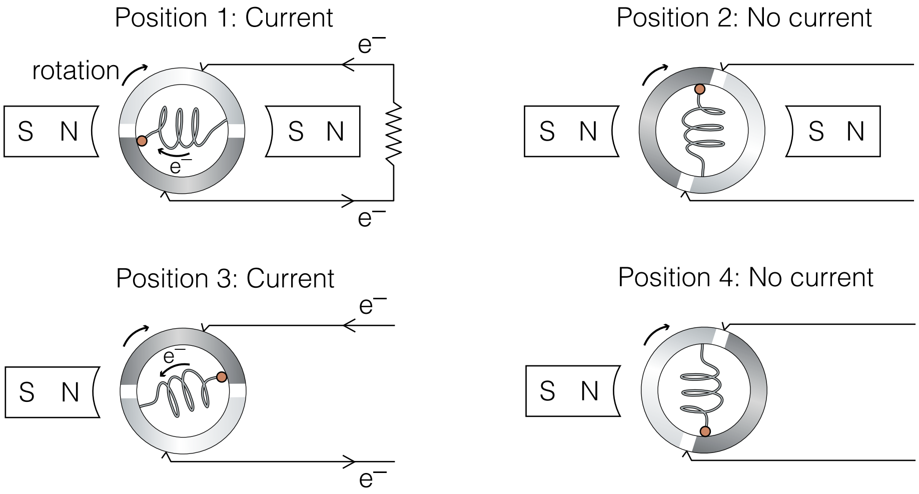


Figure 4.38B These end views of the DC generator in Figure 4.38A show the changing position of the two halves of the commutator. Current through the load is not constant, but it is one-directional.

DidYouKnow?

The current electricity that is produced by a DC generator is not the same as that produced by a battery. Although both devices produce an electric current in one direction only, the DC produced by the generator is pulses of current that coincide with the spinning of the generator. Batteries produce a smooth continuous current.

Electric Motors: Electric to Mechanical Energy

An electric motor can be constructed in exactly the same way as a generator. Instead of *producing* electricity, however, a motor *uses* electric energy to make a coil of wire spin between the poles of a magnet (the "field magnet"). This occurs because the coil (armature) is connected to a source of electric energy. Current flowing through the coil turns it into an electromagnet, which is rotated by magnetic forces from the field magnet. The fundamental law of all magnets — opposite poles attract and like poles repel — is the basis upon which electric motors function.

DC Motors

In one common design for DC motors, a rotating wire coil (an armature) becomes an electromagnet as current flows into it through a split-ring commutator. The armature is attracted and repelled by stationary field magnets near it, so it begins to rotate. The commutator acts as a switch, cutting off and then reversing the direction of current flow to keep the armature turning.

- electrons flow to the right from the battery to the commutator into the armature
- the north pole of the armature is repelled by the top of the field magnet and attracted by the bottom of the field magnet
- the armature begins to rotate clockwise (the yellow dot lets you follow the rotation)

- the commutator cuts off the current so the armature does not stall as it passes close by the field magnets
- the momentum of the spinning armature keeps it moving clockwise

- the commutator reverses the direction of current through the armature
- the ends of the armature reverse their magnetic polarity
- the top of the armature is again repelled by the top of the field magnet and attracted by the bottom of the field magnet
- the force on the armature continues to rotate it clockwise

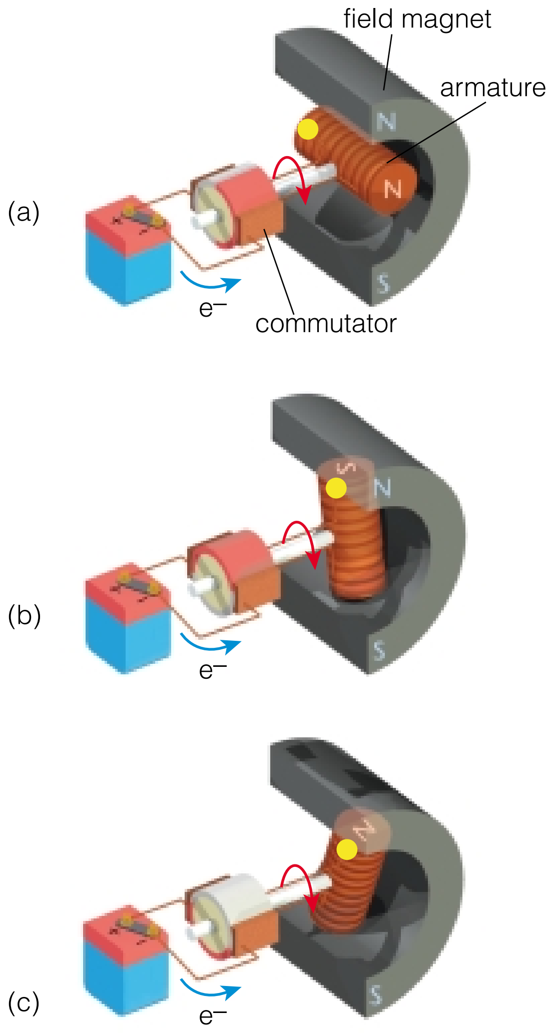


Figure 4.39 A DC motor is rotated by magnetic forces between the field magnets and the armature, which acts as an electromagnet.

PROBLEM-SOLVING

INVESTIGATION 4-H

SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Let's Get Motoring!

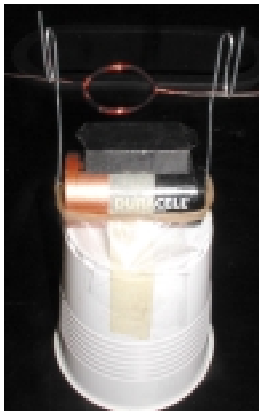
The principles by which an electric motor works are relatively simple. Constructing one from simple components can be tricky. At times, you may find you need to fine-tune certain components in order to ensure your motor works.

Challenge

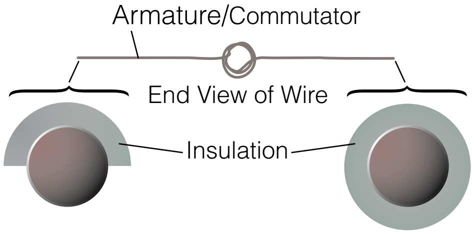
Following the specifications, construct a working electric motor using only the simple materials supplied. Troubleshoot and adjust your motor until it meets the design specifications.

Apparatus

1 D-cell
2 large paperclips
1 wide rubber band
1 plastic, paper, or Styrofoam™ cup (250 to 500 mL)
60 cm of enamel-coated magnet wire
1 rectangular or round ceramic magnet (about 1 cm thick and at least 3 cm long)
2.5 cm diameter wooden dowel or broom handle
masking tape
fine sandpaper



Note: You can make a split-ring commutator by removing insulation completely from one end of the coil wire. At the other end, remove insulation from around only half the wire, as shown.



Safety Precautions

Design Specifications

1. You can use only the materials supplied.
2. Your motor must run continuously for at least 10 s.

Plan and Construct

① Decide how you will construct your motor, using the illustrations as a guide.

② Build the motor and test it. Modify the motor until it operates successfully.

③ Draw a scientific diagram of your motor, labelling each part and the material used to build it.

Evaluate

1. Score your motor's success using the table below.
2. Describe problems you encountered in this activity and the steps you took to overcome them.

Extend Your Skills

3. Based on your experience in this investigation, make a list of at least four troubleshooting instructions that would assist students constructing this motor in the future.

	Evaluation Criteria	
Level of success	Criterion	Score Points
1	coil moves but does not rotate	1
2	coil rotates less than one-half turn	2
3	coil rotates one-half to one turn	5
4	coil rotates more than one turn but for less than 10 s	7
5	coil rotates continuously for 10 s	10

AC Motors

Electric motors found in larger appliances, such as dishwashers, washing machines, garage door openers, and furnaces, operate on alternating current. AC motors have a rotating core, or **rotor**, made up of a ring of non-magnetic conducting wires connected at the ends and held in a laminated steel cylinder. Surrounding the rotor is a stationary component called a **stator**. In its simplest form, the stator is a two-pole (north and south) electromagnet. More complex stators resemble a ring of many electromagnets, each with a north and south magnetic pole. When an AC motor is turned on, the attraction and repulsion between the magnetic poles of the stator and the rotor causes the rotor to spin.

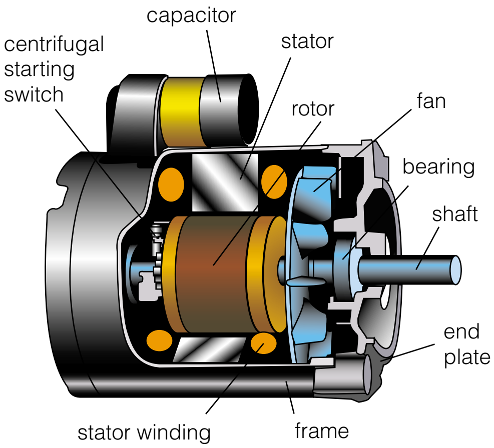
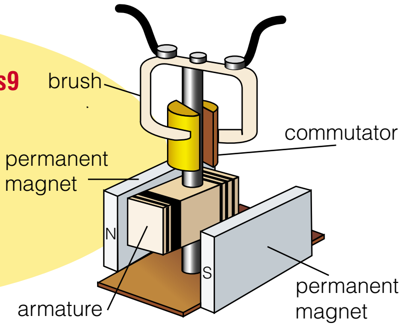


Figure 4.40 AC motors such as this one are used in a variety of larger appliances.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

The St. Louis motor was designed to teach how a DC motor works. For plans to build a working St. Louis motor, go to the web site above, and click on Web Links to find out where to go next.



The St. Louis motor

TOPIC 6 Review

1. Who first observed the connection between magnetism and electricity? What did this person observe that led to the discovery?
2. Describe at least *two* ways in which an electromagnet can be made stronger.
3. What is the difference between AC and DC? How is each type of current usually produced? Why do we use AC in our homes?
4. In what ways are electric generators and motors similar? In what ways are they different?
5. What is the function of brushes and a split-ring commutator? Where are these items used?
6. Describe what parts the following components play in the operation of a DC motor: commutator, brushes, permanent magnets, and armature.

TOPIC 7

Electricity in the Home

Do you know how power reaches your home from an electricity-generating power station? How is the power distributed through your home? How do you pay for the electricity you use?

Transmission of Electricity through the Power Grid

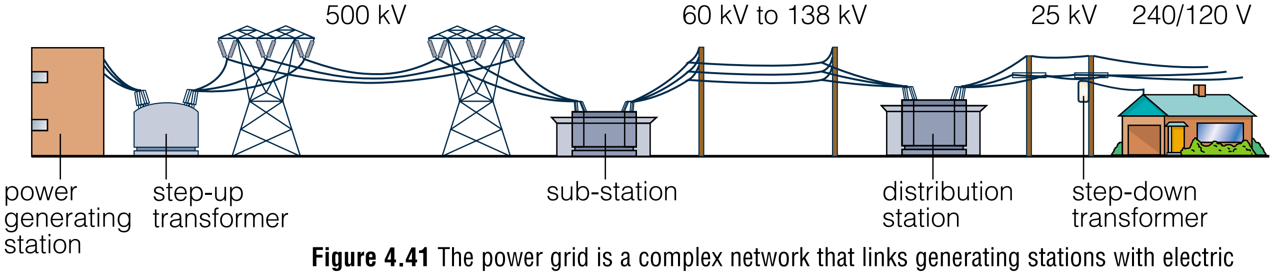


Figure 4.41 The power grid is a complex network that links generating stations with electric energy users such as homes and factories.

Alternating current for use in homes and industry is produced by large electric generators in power stations. **Transformers** are used to "step up" the voltage for efficient transmission over long distances. At the destination, other transformers "step down" the voltage to the 240/120 V used in homes and factories. There is probably a step-down transformer near your home, perched on a power pole, or in a back alley.

Find Out ACTIVITY

Build a Transformer

A transformer is composed of two coils of wire wrapped around an iron core. In this activity, you will build a simple transformer and investigate its operation.

Materials

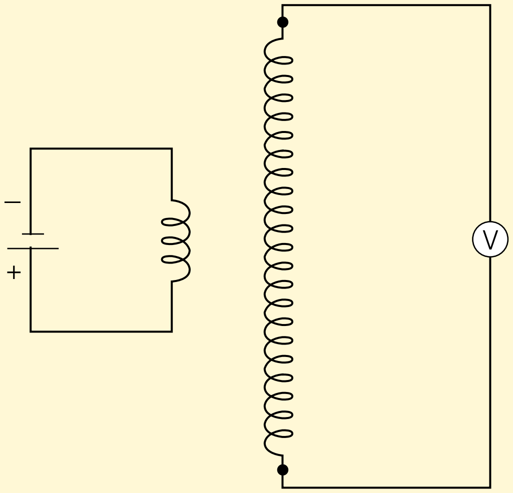
iron nail, bolt, or rod at least 10 cm long
2 lengths of magnet wire (22 or 24 AWG) about 1.5 m long
1 D-cell in holder
sensitive analog voltmeter
sandpaper (a small square)

Safety Precautions

Procedure

Performing and Recording

1. Coil half of one length of wire neatly and tightly around the nail near one end. Leave extra wire free at each end of the coil.
2. Coil most of the other wire near the other end of the nail (leave about 10 cm of wire free at each end). Do not let this coil touch the other one.
3. Sand off the insulating coating from all exposed wire ends.
4. Attach the ends of the first wire coil to the voltmeter.
5. Touch the ends of the second wire coil to the terminals of the D-cell. Observe the voltmeter reading as you connect and disconnect the cell.



What Did You find Out? **Analyzing and Interpreting**

1. What happened to the reading on the voltmeter as you connected and disconnected your transformer to the cell? What happened during the interval that the cell was connected?
2. Was your transformer connected as a step-up transformer or as a step-down transformer? How do you know?
3. Based on your observations, explain why transformers are not used with direct current.

From the Grid into Your Home

Distribution lines connect your home to the power grid through a step-down transformer and a power meter (Figure 4.42). The meter is usually mounted on the outside wall of buildings where the distribution lines enter. It records the total electric energy supplied to electric devices that are operating in the house.

After being metered, electricity then goes to a service panel. At the top of the panel, wires from the meter are connected to the main **circuit breaker**. The main breaker acts as a switch and safety device that can cut off all power coming into the home. If current exceeds a safe level, a bimetallic strip in the breaker heats up, bends, and opens the circuit. Current stops flowing until the breaker cools and you reset it.

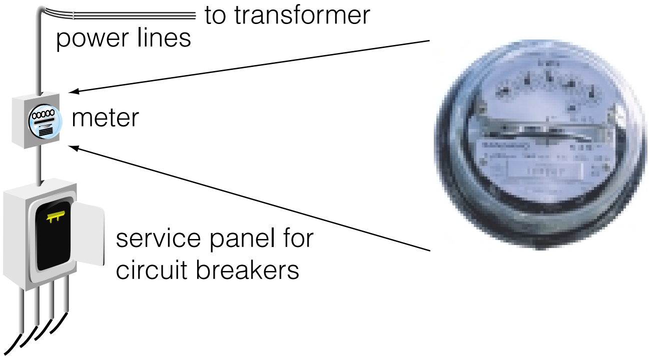


Figure 4.42 The amount of electric energy supplied to your home is measured by a meter and distributed by a service panel.

Older homes often have a **fuse** box instead of a breaker panel. A fuse contains a metallic conductor that melts when excessive current heats it up. This opens the circuit until the fuse is replaced. Fuses are rarely used in modern buildings, but they are common in electric stoves and automobile electrical systems.

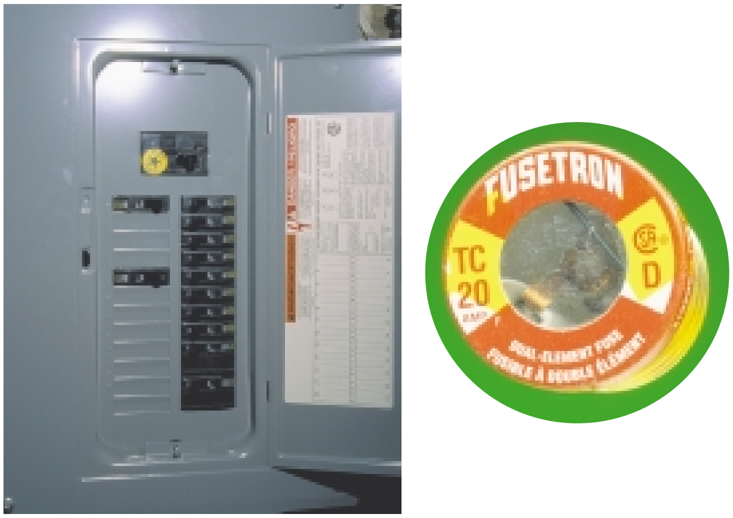


Figure 4.43 Circuit breakers (left) and fuses (right) “blow” if current becomes excessive. This fuse stops current greater than 20 A, preventing overheated wires and possible fires.

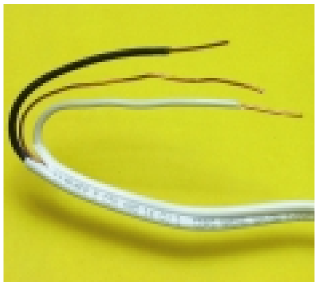


Figure 4.44 Fourteen gauge electric cable, commonly used for home wiring.
Black = hot,
white = neutral,
bare copper (sometimes green) = ground.

The lower part of a service panel contains additional circuit breakers or fuses for each **branch circuit** in your home. Each branch circuit supplies power to one or more wall plugs or lights connected in parallel by cables in the house walls. As additional loads are plugged into a branch circuit, the current flowing through the connecting cables increases. The small resistance of the cable wires causes them to heat up when enough current flows. Before the wires become hot enough to start a fire, the branch breaker or fuse cuts off current to all loads in that circuit. Because the branch circuits are connected in parallel, however, appliances or devices plugged into other branches will continue to operate.

The breakers, plugs, lights, and switches in each branch circuit are connected by electric cables that contain three wires. There are two "live" wires — a white insulated wire (usually called the **neutral wire**) and a black insulated wire (usually called the **hot wire**). The third wire, the **ground wire**, is either bare copper or covered with green insulation. In North American homes, there is a potential difference of 120V across the black and white wires, in curcuits for lamps and ordinary appliances (220-240V for kitchen ranges). The ground wire reduces shock hazards by safely channelling back into the ground any current that has "leaked" onto metal components in the electric circuit.

Home Wiring

To install or modify wiring in your home, it is usually necessary to get a permit from your city, town or municipal office. Licensed electricians who do the wiring must follow strict regulations and practise extreme caution when changing or repairing circuit components. After major wiring work is complete, an electrical inspector may need to certify that the job meets a set of standards called the **electrical code**.

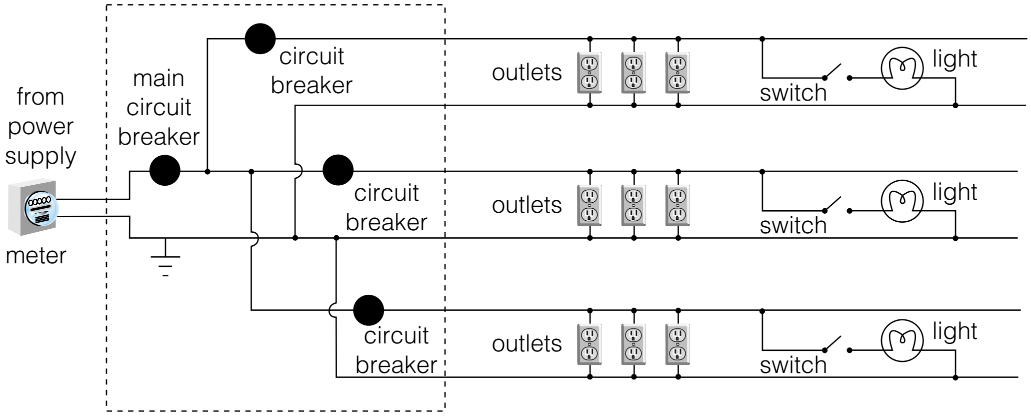


Figure 4.45 A single service panel supplies and controls current to dozens of branch circuits in a typical house. Only three branch circuits are shown in this wiring diagram.

Find Out ACTIVITY

EXTENSION

Circuit Training in Your Room

To plan the wiring in a new home, electricians and, in some cases, electrical engineers draw circuit diagrams that show where the different electric fixtures will be placed and how they will be connected. In this activity, you will have the opportunity to draw a circuit diagram of your room.

Materials

pencil
ruler
graph paper

Procedure

1. Measure your bedroom and draw an accurate scale floor plan that includes doors, windows, wall switches, electric outlets, and permanent light fixtures.

2. Find out which electric components in your room are connected together. The light switch, for example, probably does not control the wall outlets. On your plan, draw a possible wiring diagram for your room.

3. Draw a circuit diagram for your room using standard symbols for lights and switches, and a circle with an "X" inside for wall outlets.

What Did You Find Out? Analyzing and Interpreting

1. Where in your circuit compared to the receptacles and the lights would the light switch be located? Explain the reason you chose this location.

2. Describe at least three things you must consider when wiring a bedroom.

3. How is the circuit diagram for your room similar to the diagrams you have previously drawn of simple circuits? How is it different? (Give at least two answers for each question.)

Extension

4. Imagine that you wanted to add an additional receptacle to your room, controlled by the existing light switch. On your circuit diagram, show the additional electric components in a different colour. Explain the reason for each placement.

Career CONNECT

Electricity runs in Craig Terakita's family. For about 25 years, Craig has worked in his family's electrical business. Every day, he wires residences so they will have safe and efficient heating, lighting, and power. He can do it all — from applying for wiring permits and preparing cost and material estimates, to stringing electric cable through walls, installing plugs and switches, and hanging light fixtures. Craig often works eight to ten hours each day, but he enjoys being on the job with other tradespeople, even when projects require working on weekends.

"To do this job, you need a strong math background," Craig says. He spent four years in postsecondary education, taking classes and then apprenticing for between eight and 12 weeks per year. Now, as a master electrician, Craig's training and experience make him very aware of the potential danger of electricity. He treats it with great respect.

Does a career as an electrician interest you? You can learn about requirements and training opportunities from your school guidance counsellor, the library, or the Internet.

Digital Devices

Have you ever peeked at the circuit board inside a calculator or computer? The four basic circuit elements are present there, although they may take unfamiliar forms. Conductors, for example, may be thin traces of copper instead of wires. Some loads, such as resistors and lamps, resemble the components you have been using. What you do not see are the thousands or millions of tiny electronic switches that form the heart of **digital** electronic technology — machines that process numerically coded information.

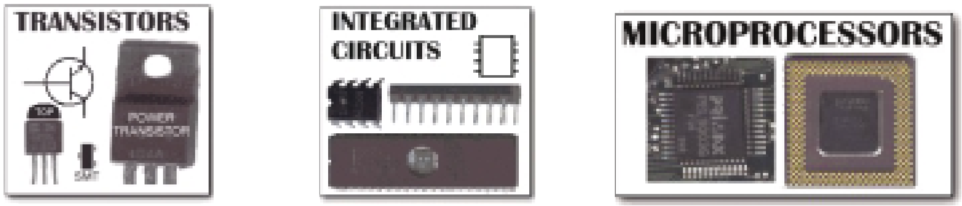


Figure 4.46 Modern digital electronic devices are based on transistors, integrated circuits with several transistors in the same case, and microprocessors (chips), which contain millions of transistors.

Switches have only two states: on or off. These states can be used to represent numbers and letters using a **binary code**, a sequence of "on" and "off" signals. In addition, logic circuits containing many switches can process binary information. For example, you can build a logic circuit that will compare two numbers, add them, or find their difference.

The electronic switches in modern digital devices are **transistors**, solid-state components that can be turned on and off by electric signals. In turn, transistors can control other signals. Every digital device you use, from your calculator to your CD player, is designed around components that contain enormous numbers of transistors (Figure 4.46).

DidYouKnow?

Most digital devices operate on direct current. The power cube transformers (adapters) that allow personal electronic equipment to operate from household power convert 110 V AC to low-voltage DC that replaces energy from batteries.

Cool Tools

Devices called "surge suppressors" (or "surge protectors") are often used to protect expensive electronic equipment, such as computers, televisions, stereos, home theatre systems, and fax machines. Surges of electric charge, which are momentary increases in the energy (voltage) of the supply to tens of thousands of volts, can occur through household electric wiring and also through telephone lines and coaxial cable. Surges can be caused by lightning, by turning on or off large appliances, or by a local power company transferring large amounts of electricity into or out of the power grid.The suppressor absorbs some of the electric surge and then diverts the rest to the ground.

Measuring Electric Power

In physics, **power** is defined as energy per unit time. Electric power describes the amount of electric energy that is converted into other forms of energy (heat, light, sound, or motion) every second. As well, electric power can also describe the amount of electric energy that is transferred from one place to another in a certain amount of time. The symbol for power is P. The mathematical equation that defines power is:

$$\text{Power (in watts)} = \frac{\text{Energy (in joules)}}{\text{Time (in seconds)}}$$

$$P = \frac{E}{t}$$

The units of power are joules per second. One joule per second is also called one watt (W) in honour of James Watt (1736–1819). A 100 W light bulb, for example, converts 100 W of electric energy into light and heat every second. A kilowatt (kW) is 1000 watts.

Electric power is not usually calculated directly by measuring energy and time. It is much more common to measure the voltage and current in a circuit and use these quantities to calculate power.

$$\text{Power (in watts)} = \text{Current (in amps)} \times \text{Voltage (in volts)}$$

$$P = IV$$

This equation can be manipulated to determine the current or the voltage of the circuit.

$$\text{Current} = \frac{\text{Power}}{\text{Voltage}} \qquad I = \frac{P}{V}$$

$$\text{Voltage} = \frac{\text{Power}}{\text{Current}} \qquad V = \frac{P}{I}$$

Word CONNECT

One watt is a relatively small amount of electric power. Electric power production and transmission involves much more power, which is expressed as:

kilowatts (kW) = 1 000 W

megawatts (MW) = 1 000 000 W

gigawatts (GW) = 1 000 000 000 W

Model Problem

A current of 13.6 A passes through an electric baseboard heater when it is connected to a 110 V wall outlet. What is the power of the heater?

Given

$I = 13.6$ A
$V = 110$ V

Required

Power, P, in watts (W)

Analysis

Since you know the potential difference and the current, use the equation $P = IV$ to calculate the power.

Solution

$$\begin{aligned} P &= IV \\ &= 13.6 \text{ A} \times 110 \text{ V} \\ &= 1496 \text{ W} \\ &= 1.50 \times 10^3 \text{ W} \end{aligned}$$

Paraphrase

13.6 A of 110 V current passing through an electric heater is a power of 1.50×10^3 W.

Pause& Reflect

Review the units and symbols for the new quantities that you have learned. Add the unit and symbol for power to the table in your Science Log. Include the relationships between watts, joules, and seconds.

Practice Problems

1. What is the power (in watts and kilowatts) of a hair dryer that requires 10 A of current to operate on a 120 V circuit?
2. The maximum current that a 68.5 cm television can withstand is 2 A. If the television is connected to a 120 V circuit, how much power is the television using?
3. A 900 W microwave oven requires 7.5 A of current to run. What is the voltage of the circuit to which the microwave is connected?
4. A flashlight using two 1.5 V D-cells contains a bulb that can withstand up to 0.5 A of current. What would be the maximum power of the bulb?

Paying for Electric Energy

Producing and distributing electric energy is expensive. Power companies pass their costs on to customers according to the amount of energy supplied to each user. To determine this amount, a power company employee records the reading on every customer's electricity meter at regular intervals.

You can read an electric meter yourself. On the meter, each dial represents one digit in a five-digit number. When a dial pointer is between numbers, the lower number is recorded (Figure 4.47). For convenience, most power companies measure electric energy in a customary (non-SI) unit — the kilowatt hour (kWh). One kilowatt hour is the total energy supplied to a 1000 W load during 1 h of operation. For example, a small hair dryer might be rated at 1000 W (1 kW). If it ran for 1 h, the dryer would have transformed 1 kWh of electric energy into thermal energy.

DidYouKnow?

James Watt (1736–1819), a Scottish engineer, is known for improving the efficiency of the steam engine. To describe the power of steam engines and other devices, he compared them to horses. Watt defined the power of a strong horse as one horsepower. One horsepower equals 746 W. What is the power in watts of a small car with a 100 hp engine?

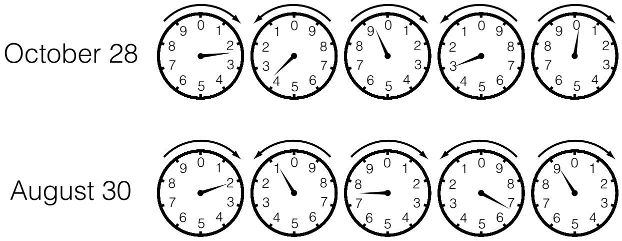


Figure 4.47 The bottom row of meter dials show an August 30 reading of 20 769 units. The top row of dials show an October 28 reading of 23 930 units. The power company would bill this customer for 3161 units of electric energy.

Model Problem

A family uses 3000 kWh of electric energy in a two-month period. If the energy costs 11.0 cents per kilowatt hour, what is the electric bill for the period?

Given

$E = 3000$ kWh
Unit cost = 11.0 cents per kilowatt hour

Required

Total cost in dollars

Analysis

Convert unit cost from cents to dollars. Then find the total cost by using the following formula.
Total cost (dollars) = Total energy used in kWh × cost in \$ per kWh

Solution

Total cost

$$= 3000 \text{ kWh} \times \frac{\$0.11}{\text{kWh}} = \$330.00$$

Paraphrase

The cost of electric energy used in this home over a two-month period was \$330.

Practice Problems

1. (a) If a refrigerator requires 700 W of power to function, how many kilowatt hours of power will it require in a 30-day period?

(b) If electricity costs 11 cents per kilowatt hour, how much would the refrigerator cost to operate in that period?

2. A home-owner finds that she has a total of 42 light bulbs (100 W) in use in her home.

(a) If all of the bulbs are on for an average of 5 h per day, how many kilowatt hours of electricity will be consumed in a 30-day period?

(b) At 11 cents per kilowatt hour, how much will operating these lights cost the home-owner during that period?

(c) How much money would the home-owner save if she switched all of the bulbs to energy-saving 52 W light bulbs?

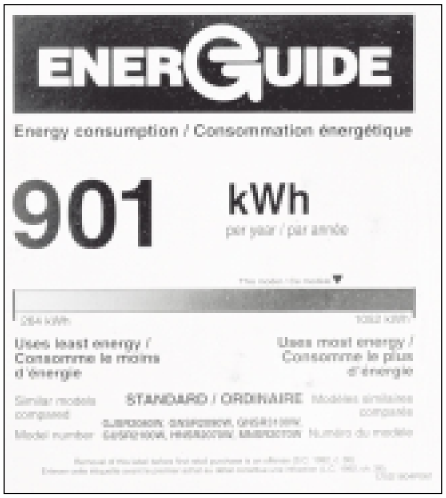
3. Bob has a stereo that operates at 120 V, using 2.5 A of current.

(a) How much power does Bob's stereo need to operate? (Hint: Think back to the previous power-calculation Practice Problems.)

(b) If Bob plays his stereo for an average of 5 h each day, how much electricity will he use in a 30-day period?

DidYouKnow?

The amount of energy a person uses on a low-activity 24 h day is about the same as the energy that a 100 W light bulb uses when it is on for 24 h. People, of course, obtain energy from food.



ENERGUIDE

Energy consumption / Consommation énergétique

901 kWh per year / par année

264 kWh

1052 kWh

Uses least energy / Consomme le moins d'énergie

Uses most energy / Consomme le plus d'énergie

Similar models compared

STANDARD / ORDINAIRE

Modèles similaires comparés

Model number

Numéro du modèle

Figure 4.48 A power rating or yearly energy use information is marked on most electric devices.

Power Rating

Many electric appliances, such as hair dryers, electric kettles, and even light bulbs, have a power in watts marked on them. This rating tells you how many joules of energy the device uses in every second of operation. (Remember, 1 W is 1 J/s.)

"EnerGuide" labels, such as the one shown in Figure 4.48, help people to make comparisons of energy use when purchasing large home appliances. Stoves, refrigerators, washers, dryers, air conditioners, and similar appliances sold in Canada carry EnerGuide labels. The large number at the top of the label indicates the approximate amount of energy the appliance will use in one year of typical operation. The coloured bar on the label shows how that particular appliance compares with others on the market. The numbers on the bar give the yearly energy use of the most efficient (left end) and least efficient (right end) appliances of similar type. EnerGuide ratings are assigned after appliances are tested according to standard procedures accepted by the Canadian Standards Association (CSA).

Together, all the appliances in your home require a surprisingly large amount of electrical power. Examine Table 4.9 to find some typical examples. In the next investigation, you will determine how your household uses electric energy.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Most major power companies offer electric power-consumption calculation tools on their Internet sites to help you find out where your family's power consumption dollars are going. Many power company sites also offer energy conservation suggestions. To find some that you could begin to use, go to the web site above, and click on Web Links to find out where to go next.

Table 4.9 Power Ratings and Energy Use for Appliances

Appliance	Power P (W)	Average energy used per year (MJ)	Appliance	Power P (W)	Average energy used per year E (MJ)
clothes dryer	4356	3600	CD player	85	500
dishwasher	1200	1300	TV (colour)	200	1600
range and oven	12 200	4200	washing machine	512	400
refrigerator	615	6600	water heater	2475	5000

INVESTIGATION 4-I

SKILLCHECK

Initiating and Planning

- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

You've Got the Power!

Think about how electricity is used in your home. Which appliances are costing you the most to operate? Which cost you the least? What would be the easiest way to reduce your household's electricity bill and perhaps help the environment without major changes in your lifestyle?

What To Do

① Construct a large data table in which to record the information you collect.

② At home, list all of the major and minor electric appliances or devices that are used in your home.

③ For each device, try to estimate the average number of hours per day (and then per month) that it is used. Ask members of your household for their input or check a power company website for average values.

④ For each device, record any information you can find that is related to the wattage, voltage, or amperage required by the device. Consult the appliance power-consumption reference sheet supplied by your teacher for wattages you cannot determine. If wattages cannot be found for certain devices, attempt to calculate power use by using data for voltage and current and the equation (watts = volts × amps) you learned earlier. The voltage of a standard receptacle is 120 V.

⑤ Calculate the number of kilowatt hours of electricity consumed by each device in a month. From these values, determine the total monthly electricity consumption by your household.

⑥ Use the current rate your household is paying for electric power to calculate the monthly power bill. (You can find the current rate per kilowatt hour from a recent electric bill or by contacting the local power company.)

Analyze

1. Which appliances or devices did you find were costing you the most money in terms of electricity consumption? Which cost the least? Explain why you think this was the case. Give at least two explanations for each of the high- and low-cost devices.

2. Suppose that your goal is to reduce your power bill by $25.00 over a 30-day period.

(a) At the rate your household is currently paying for electricity, by how many kilowatt hours of power would you need to reduce your consumption to save $25.00 in a 30-day period? Show your detailed calculations.

(b) Describe in detail what measures you could take to reduce your electricity consumption by the number of kilowatt hours you calculated in question 2 (a).

Electric Devices and Efficiency

If an electric light bulb were perfect, all of the electric energy it took in (input energy) would be converted into light (useful output energy). No real device, however, is a perfectly efficient energy converter. Some input energy is always converted into waste heat.

You can express efficiency as a percentage by using the following mathematical relationship.

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

To find the efficiency of electric devices, it is often necessary to calculate energy inputs or outputs.

To determine the electric energy input of a device, the formula for power $\left(P = \frac{E}{t}\right)$ can be manipulated to solve for energy.

$E = Pt$ or energy (joules) = power (watts) × time (seconds)

Different types of electric lighting provide a good example of differences in efficiency.

Incandescent Bulbs

Electric lighting in most homes is largely provided by incandescent light bulbs, which are only about 5% efficient. About 95% of the input electric energy is converted to waste heat as current passes through a thin metal filament coiled inside the bulb.

Halogen Bulbs

Halogen bulbs are filled with a high-pressure gas containing traces of iodine, which helps prevent their filament from evaporating. This allows the bulbs to operate at very high temperatures, so they convert a greater proportion of their input energy into light. Although halogen bulbs are about 15% efficient, they still waste a significant amount of energy as heat and can be a fire hazard. Halogen bulbs last two to six times longer than incandescent bulbs.

Fluorescent Tubes

A fluorescent tube contains a gas such as mercury vapour. When current passes through the vapour, it emits energy that affects a white material on the inside of the glass, causing it to glow. Fluorescent tubes operate at relatively low temperatures, so they waste very little energy as heat. Most fluorescent tubes are about 20% efficient, and they last ten to 13 times longer than incandescent bulbs. Compact fluorescent bulbs are much more expensive than the regular light bulbs which they can replace. Fluorescent bulbs' long lifetime and low power consumption, however, more than repay this initial cost. By using less electricity, compact fluorescent bulbs also reduce the environmental impact of generating their operating power.

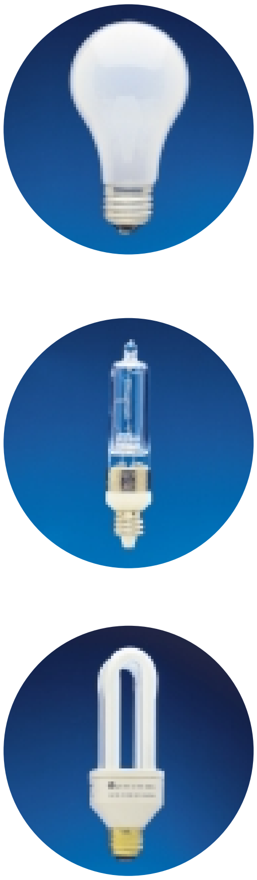


Figure 4.49 Replacing traditional light bulbs with more efficient compact fluorescent bulbs (bottom) can significantly reduce energy requirements and operating costs for electric lights.

Model Problem

A 1000 W electric kettle takes 4.00 min to boil some water. If it takes 1.96×10^5 J (196 000 J) of energy to heat the water, what is the efficiency of the kettle?

Given	**Required**
$P = 1000$ W	Efficiency
$t = 4.00$ min	
Useful energy output $= 1.96 \times 10^5$ J	

Analysis

To find the energy used by the kettle, use the formula $E = Pt$.
To find the efficiency of the kettle use

$$\text{efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} \times 100\%$$

Solution

Convert time into seconds.

$$t = 4.00 \text{ min} \times \frac{60 \text{ s}}{\text{min}} = 240 \text{ s}$$

Find the electric energy input to the kettle.

$$\begin{aligned} E &= Pt \\ &= 1000 \text{ W} \times 240 \text{ s} \\ &= 240\,000 \text{ J} \\ &= 2.40 \times 10^5 \text{ J} \end{aligned}$$

Find the percent efficiency.

$$\text{efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} \times 100\%$$

$$\text{efficiency} = \frac{1.96 \times 10^5 \text{ J}}{2.40 \times 10^5 \text{ J}} \times 100\% = 81.7\%$$

Paraphrase

The kettle is about 81.7% efficient.

Practice Problems

1. Find the efficiency of a 23 W fluorescent tube that is used 4.0 h per day and in that time produces 6.624×10^4 J of useful light energy.
2. A 100 W incandescent bulb also produces about 6.624×10^4 J over a 4.0 h period. What is the efficiency of this bulb?
3. Based on your answers to questions 1 and 2, how much money would you save in a 30-day month if you replaced 25 of the 100 W incandescent bulbs with 23 W fluorescent bulbs? Assume that the bulbs operate 4 h daily, and that electricity costs 10¢ per kilowatt hour.

Math CONNECT

Look again at the mathematical relationship that defines efficiency. High efficiency (near 100%) means the useful output energy is almost the same as the input energy. Very little energy is transformed into waste heat. *High* efficiency means *low waste*. What would it mean for a device to have efficiency greater than 100%? Do you think this is possible?

Home Electric Safety

It does not take a very large electric current to do serious damage to a person. Electricity-related injuries often occur when a person's body accidentally becomes a conducting pathway by which electricity can reach the ground. Current flowing through the body — an electric shock — can cause pain, muscle spasms, and even death. In addition to injuring people directly, electrical faults are a common cause of household fires. Fortunately, simple safety measures can help to prevent you from being harmed by electricity.

- Do not overload an outlet or a circuit by plugging in too many electric devices. Overloading can cause the wiring to heat up and could lead to a fire.
- Never work on or clean appliances that are still plugged in. You might touch a "hot" wire and become a path to the ground.
- Replace frayed or worn out electric cords. If a person touches the exposed wires, electric current may flow through the person's body rather than through the load. If the bare wires touch directly (a **short circuit**), a high current flows between them, causing sparks and often starting a fire.

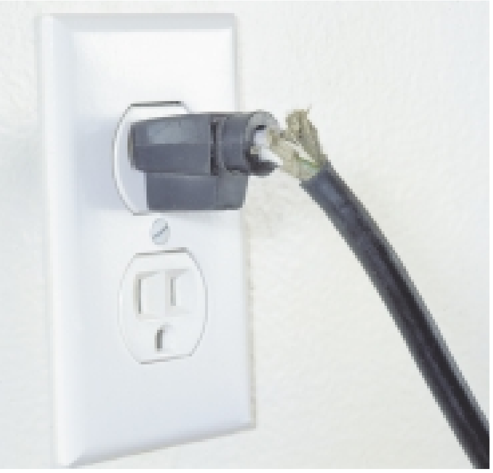


Figure 4.50 Frayed electrical cords are a serious shock and fire hazard.

- Use receptacle covers on easily accessible outlets to prevent small children from sticking objects into receptacles, causing short circuits or shocks.
- Never use appliances close to a sink or bathtub with water in it or when your hands are wet.

Cool Tools

Emergency medical personnel sometimes use an electric *defibrillator* to apply a controlled electric shock to an accident victim's heart muscle. If the heart has stopped, the shock can cause it to contract and begin beating again. If the heart muscle is contracting in uncontrolled spasms, its normal rhythm can be restored by the shock, which is applied through a paddle-shaped electrode. Some portable defibrillators even "speak" computer-generated instructions to guide inexperienced users.

DidYouKnow?

You have probably seen outlets with reset buttons, such as the one in the photograph. These buttons indicate that the outlet is connected to a ground fault circuit interrupter (GFCI). These devices are required in areas such as bathrooms and outdoor locations where water and electricity create a hazard.

A GFCI monitors current flowing into and out of a load. If any electricity is diverted out of the circuit wires, the GFCI immediately cuts off the current. If the problem is caused by electricity leaking from the load and through a person's body to the ground, opening the circuit could prevent a potentially fatal electric shock.

Electric Safety Outdoors

Electric hazards exist outdoors as well as inside your home. Power poles, transformers, substations, and overhead wires can all be dangerous. To protect yourself from a possibly fatal electric shock, you should follow a few simple rules.

- Never allow your body or something you are holding to come into contact with live electric wires. Touching a kite string, ladder, branch, or TV antenna that is in contact with power wires can make you a pathway to the ground, causing electricity to flow through your body.
- Never use ungrounded or frayed two-prong electric cords outdoors.
- Do not operate electric equipment outdoors when it is raining.
- Before digging deeply in your yard, make sure that there are no underground utility cables. A shovel can cut through buried communications wires and disrupt telephone or cable television service. Heavy equipment or power posthole diggers can pierce the insulation of underground power cables, creating a risk of serious shock for the equipment operator as well as causing a power outage. Utility companies will send an employee to your property on request, to locate and mark underground wires and pipes without charge.

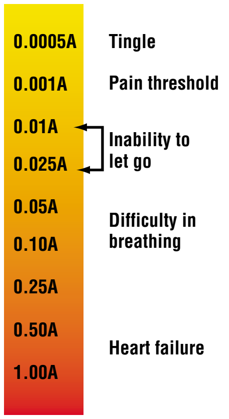
Off the Wall

Effects of Electric Current

The scale shows how the effect of electric current on the human body depends on the amount of current that flows into the body. The average circuit in a home carries a maximum current of 15 A. Extreme caution must be used when dealing with electricity because of the danger that this level of current poses.

Effects of Electric Current

The scale below shows how the effect of electric current on the human body depends on the amount of current that flows into the body.



TOPIC 7 Review

1. Describe the purpose and location in the power grid of:
   - (a) step-up transformers
   - (b) step-down transformers
2. Calculate the cost of using a 300 W television for:
   - (a) 6 hours when electricity costs \$0.11 per kWh.
   - (b) 300 hours when electricity costs \$0.16 per kWh.
3. Describe the difference between a circuit breaker and a fuse.
4. Describe three ways in which electric energy could be conserved with respect to home lighting.

TOPIC 8

Electricity Production and the Environment

Canadians use about 2 000 000 000 000 000 000 J (2×10^{18} J) of electrical energy every year. Powering the generators that provide this electricity is an enormous task that has significant environmental effects.

Electric Energy from Burning Fuels

Fuel oil, natural gas, and coal, are burned in large **thermo-electric**—generating plants to produce about one quarter of our country's electricity. These fossil fuel resources are being consumed faster than they are produced in nature, so they are considered **non-renewable resources**.

Biomass, solid material from living things, can also be burned to power thermo-electric generators. Trees, agricultural crops and crop wastes, aquatic plants, wood, animal wastes, and municipal wastes: all these substances can be used as fuels, or turned into fuels and used to generate electricity. Biomass is considered a **renewable** energy source because it can be continually replenished.

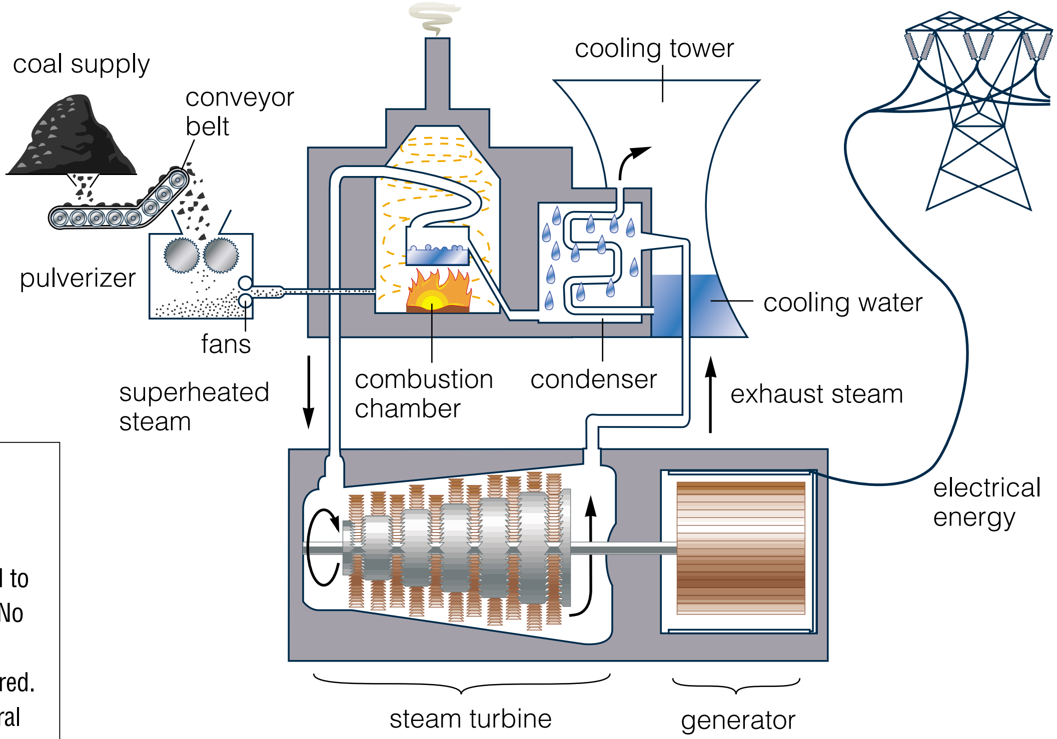


Figure 4.51 Heat from burning coal converts water into steam. The high-pressure steam flows through pipes into a turbine. The spinning turbine turns a generator that produces electric energy. Steam leaves the turbine cooled, condensed, and recycled through the turbine.

Cool Tools

Turbogenerators use exhaust gases from burning fossil fuels to spin a turbine coupled to an electric generator. No steam, condenser, or cooling tower is required. In Alberta, some natural gas production facilities generate electricity with turbogenerators fueled by *flare gas*, a waste product from the facility.

Find Out **ACTIVITY**

Seek the Source

How does electrical production in Alberta compare to other parts of our country? In this activity, you will contrast the most common sources of electric energy in Canada.

Procedure

1. Use the map below and draw *one* bar graph that shows each of the following variables for regions with total production of more than 1000 GW•h. Shade or colour code the four graph bars for each region and include a legend (key) to the code.
   - total electricity production
   - electricity from *thermo-electric* sources
   - electricity from *hydro-electric* sources
   - electricity from *nuclear* sources

Computer CONNECT

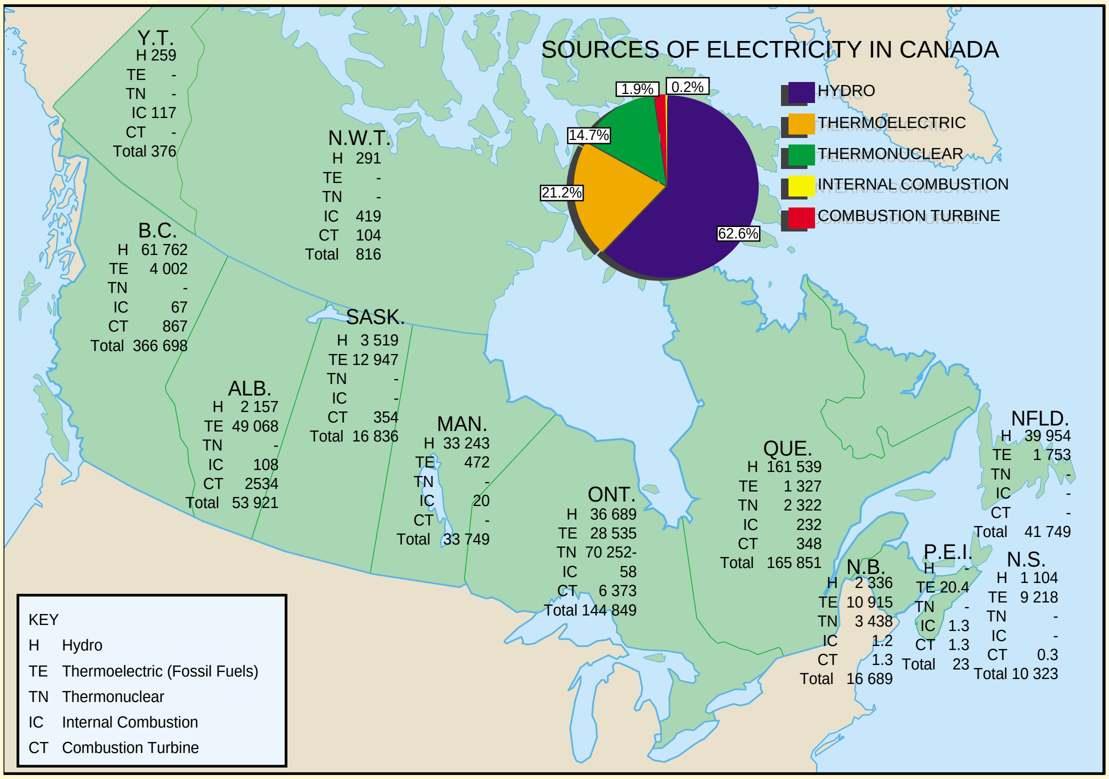
Use a computerized spreadsheet/graphing program to draw the bar graph.

What Did You Find Out? **Analyzing and Interpreting**

1. How does total electrical energy production in Alberta compare to that in other provinces? What percentage of Canada's electricity is produced in Alberta?
2. Which source of energy supplies most of Alberta's electricity? How does the electricity production in other provinces from this source compare to that of Alberta?
3. Rank the sources of electricity in Canada from highest to lowest.

Extension

4. Explain why Alberta, B.C., and Ontario produce most of their electricity in different ways.
5. Identify sources of electrical production other than the five mentioned on the map. Explain why each method is not more widespread.



Recent annual values for the amount of electric energy generated in each province are given in GW•h (gigawatt hours). A GW•h is a huge amount of energy: 3.6×10^{12} J. (source: Statistics Canada)

INQUIRY

INVESTIGATION 4-J

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- ✹ Analyzing and Interpreting
- ✹ Communication and Teamwork

Efficiency of Electric Lighting from Coal

In every step in the process of mining coal, generating electricity, transmitting it to your home, and lighting a lamp, some energy is used or escapes in the form of thermal energy in the process. In this investigation you will examine the efficiency of operating electric lights with power produced by coal-burning generators.

Question

What percent of the energy originally stored in the coal is actually converted into the electricity used in a lightbulb?

Hypothesis

Examine the information about electricity production that is given below. With your classmates, discuss how to use the figures given to estimate an answer to the question. Calculate an estimate and explain how you arrived at it.

Summary of steps in converting energy stored in coal to electric energy, and to then light in a lamp.

1. *Mining the coal*: Mining coal uses relatively little energy compared with the energy stored in the coal that is produced. About 1% of a typical mine's coal production would supply enough energy to operate the mine. The remaining 99% of the mine's energy output is available for other uses.
2. *Transportation of coal*: Moving coal from the mine to the power plant uses some energy to power the train. The efficiency of transporting coal is about 97%.
3. *Generation of electricity*: Thermo-electric generating plants are not very efficient. Most of the energy from the coal escapes from the stacks or from coolant water as heat. Only about 33% of the energy from the coal that is burned is converted into electricity.
4. *Transmission of electricity*: When electric energy travels through power lines, some of the energy goes into heating the conductors. Electric power transmission is about 85% efficient.
5. *Conversion to light*: Incandescent light bulbs are very inefficient. Most of the electric energy is converted to heat. At best, an incandescent light bulb will be about 15% efficient.

In this investigation, you will start with an amount of coal that has 1 million joules (1 000 000 J or 1.0×10^6 J) of stored energy. You will determine the amount of useful energy that remains after each step in the process. Then you will determine the overall efficiency of the process.

Procedure

1. Make a table with the headings shown below. Allow enough rows for all the steps listed in the summary. Give your table a title.

Step	Energy at beginning of step (J)	Efficiency of step (%)	Energy at end of step (J)	Overall efficiency (%)
mining	1 000 000			

2. In the first column, write the names of the steps in the process of converting the energy stored in coal into electric energy.
3. In the second column, write the percent efficiency of each step.
4. Determine the amount of stored energy that remains after the process described in each step. You can determine this value by using the following formula.

Stored energy remaining =

$$\text{Energy remaining in previous step} \times \left(\frac{\text{efficiency}}{100\%}\right)$$

For example, the stored energy remaining after the first step is

$$\text{Stored energy remaining} = 1\,000\,000\text{ J} \times \left(\frac{99}{100}\right)$$

$$= 990\,000\text{ J}$$

Write the answer in the third column. Then 990 000 J will be the “energy remaining” in the previous step when you do the calculations for the second step. Complete all the calculations for “Stored energy remaining.”

5. In the third column, compare the remaining energy to the original energy of the coal. You can calculate this value with the following formula.

Overall efficiency =

$$\frac{\text{Stored energy remaining} \times 100\%}{1\,000\,000\text{ J}}$$

Write your results in the last column.

Analyze

1. Which step or steps in the conversion process is most efficient? Which step is least efficient?

2. What is the overall efficiency of converting the energy stored in coal to the energy of light from a light bulb?

Conclude and Apply

3. Carefully examine each step in the conversion process. Using your past studies as background, describe a way in which the efficiency of each step could be improved.

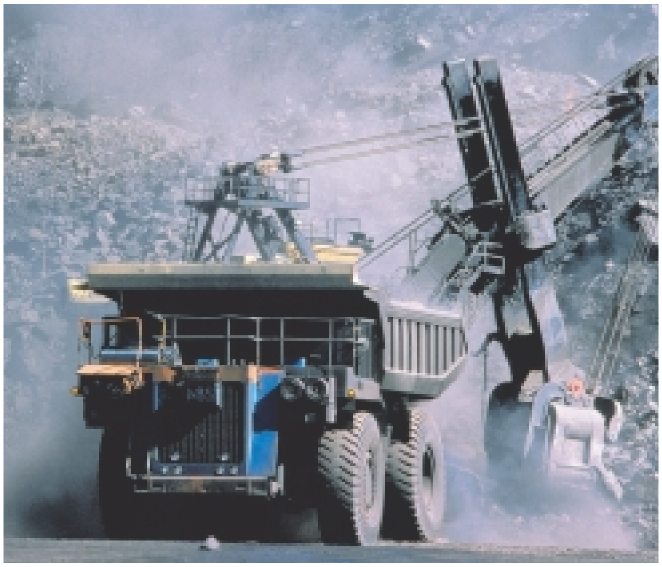


Figure 4.52 Open-pit mines affect land, water, and wildlife so much that projects such as the Cheviot Mine near Jasper have been abandoned after protests by environmentalists.

Fossil Fuels Affect Land and Air

Coal is the most common fuel for thermo-electric power plants in Alberta. Known reserves in this province are huge, enough to provide for as much as 800 years of domestic consumption. Production and use of coal, however, have serious environmental side effects. **Open pit mining** of surface deposits disturbs soil and vegetation (see Figure 4.52). Underground mines produce waste materials called "tailings," which accumulate near the mine. Water used in the mining process or seeping through the tailings becomes acidified and contaminated.

When fossil fuels, including coal, are burned to generate electric energy, contaminants such as visible particles and invisible gases escape from the smokestacks. Electrostatic precipitators can remove most of the solid particles, but they cannot remove contaminating gases, such as sulfur dioxide (SO_2).

Sulfur dioxide is one of the causes of acid rain, which harms plant and animal life. Antipollution systems called **scrubbers** can remove sulfur dioxide. Scrubbers spray a water solution through the waste gases. Most, but not all, of the SO_2 and other pollutants react with chemicals in the water and are removed.

Even if there were no contaminants such as SO_2, complete burning of pure coal or natural gas would still produce carbon dioxide gas (CO_2). Carbon dioxide is a natural part of the atmosphere. Every time you exhale, you breathe out some carbon dioxide. However, carbon dioxide is a **greenhouse gas**, which means that it helps delay the escape of heat from Earth's atmosphere. If too much carbon dioxide, methane, and other greenhouse gases accumulate in the atmosphere, they absorb more heat from the surface of Earth. This could lead to a rise in the average temperatures on Earth — global warming.

The increased concern for the environment has led to more power-generating plants that burn natural gas rather than coal. Natural gas burns much cleaner than coal, producing less SO_2. As electricity demand increases, this fuel, although somewhat more expensive, is an attractive alternative.

DidYouKnow?

Wastes decomposing in landfills produce "landfill gas," which can be used as a fuel for thermo-electric plants. This process is used on a small scale in Edmonton's Clover Bar landfill. Landfill gas is largely methane, the same chemical as natural gas.

Electric Energy from Flowing Rivers

Hydro-electric plants, use water pressure to generate electric energy. Large dams cause the water level to rise high above the power plant, which is often located inside the dam. In previous science courses, you learned that as the water depth increases, the pressure at the bottom becomes very large. Figure 4.53 shows how water flowing under great pressure is used to produce electricity.

A channel, called a penstock, directs the water from the bottom of the reservoir to a turbine. The high pressure of the rapidly flowing water turns enormous turbines, which then turn electric generators. The energy of the water stored in the reservoir is converted into electric energy. High voltage power lines carry the resulting electricity over many kilometres from the hydro-electric plant to cities, towns, and farms.

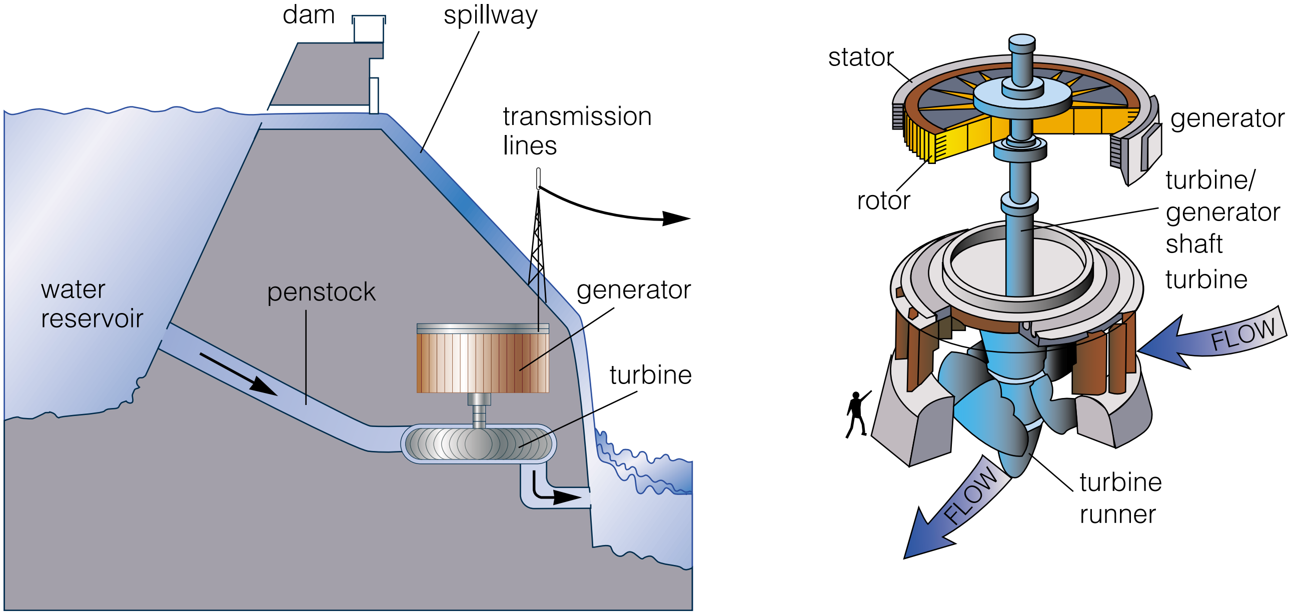


Figure 4.53 Energy is stored in the reservoir due to the tremendous mass of water and its height above the base of the dam. The turbine and generator convert this stored energy into electric energy.

Hydro-electric power plants appear to be a very clean form of electric energy generation. They have no smokestacks and they use no radioactive materials. However, reservoirs, which store water behind the dams, flood many hectares of valuable land. Homes, small villages, and even entire towns may need to be moved, displacing people and industries. When land is flooded, submerged vegetation decays. Micro-organisms responsible for this process use up the oxygen supplies in the water and sometimes decaying matter produces methane gas. These conditions make it impossible for some species of fish to survive. Other forms of life, such as algae, take over and change the ecosystem. No matter where the dam is built, some form of life is threatened.

Energy from Atomic Reactions

Bombarding uranium atoms with tiny particles called neutrons causes the uranium to split into two smaller atoms. In this process, called **nuclear fission**, a tremendous amount of energy is released. Figure 4.54 shows the process of **thermonuclear** electric generation.

The fission reactions produce tremendous amounts of heat, which is carried away from the reactor core by a coolant. Pipes carry the coolant through a tank of water, producing steam. From this point, the process is very similar to a thermo-electric–generating station. The steam turns a turbine connected to a generator that produces electricity. Steam leaving the turbine is cooled, condensed, and recycled. The waste heat is released into the environment.

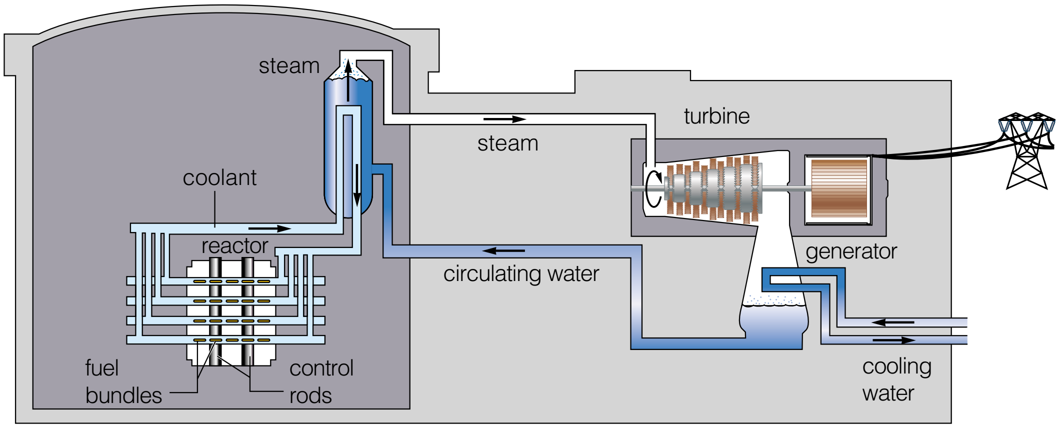


Figure 4.54 This simplified diagram shows how a CANDU (Canadian Deutrium Uranium) reactor produces electricity from nuclear energy. CANDU reactors are designed and built in Canada and have been sold around the world.

Fission reactors do not release soot or gases that cause acid rain, nor do they release greenhouse gases. However, used (spent) reactor fuel is highly radioactive for thousands of years. This means it emits high-energy particles and rays that can damage living tissues. Safe handling, transportation, and storage of these radioactive waste materials are unsolved environmental problems.

The reactors themselves also become slightly radioactive after years of use, so they are difficult and expensive to decommission.

Another type of nuclear reaction, however, does not produce large quantities of radioactive waste. In the Sun and other stars, **nuclear fusion** joins very small atoms to form a larger atom. Huge amounts of energy are released in this process. Scientists have produced controlled fusion reactions experimentally, but only for seconds. Developing technology to create and use continuous controlled fusion as a power source is an extremely difficult and expensive project that will take many decades.

DidYouKnow?

There are no nuclear power stations in western Canada. Many European countries are phasing out their nuclear power stations in favor of more environmentally friendly energy sources.

Heating the Environment

All thermonuclear and thermo-electric–generating plants release thermal energy into the environment. Seventy percent of the thermal energy from nuclear fuel and 43% from coal, oil, and gas leave the plant in the cooling water. **Thermal pollution** occurs when this warm water is returned directly to the lake or river from which it is taken, increasing the water temperature. Even a change of a few degrees can affect the plant and animal life in the water. Organisms adapted to one temperature will not thrive at another, even similar, temperature. Organisms not usually found in the lake or river may begin to replace the original species. To reduce thermal pollution, large generating plants have cooling ponds or towers where waste water can return to the temperature of the surroundings before it is released.

Cogeneration

It makes environmental sense to design electricity-generating stations as **cogeneration systems** that produce electricity and also supply thermal energy, such as hot water or steam, for industrial or commercial heating. Cogeneration power plants are often built near industrial complexes. The plant provides electricity and heat or steam to the industry and may sell excess electricity to the provincial power grid. One example of this type of facility is the Poplar Creek power plant located near Fort McMurray. The power plant provides electricity and heat needed to extract oil from the tar sands and then adds any surplus electricity to the Alberta power grid. Not only do these types of plants reduce the amount of energy wasted, they also reduce the dependence of large industrial power users on the Alberta electricity grid. This reduced demand makes it easier to meet the electricity needs of the rest of the province's consumers.

DidYouKnow?

Distribution of electric power can also cause environmental problems. Power grid transformers built before 1977, for example, often contained insulating chemicals called "polychlorinated biphenyls" or PCBs. PCBs persist, bioconcentrate, and can cause health problems if they are released when aging transformers are replaced. Some people are concerned that high-voltage transmission lines themselves, which produce radiation similar to radio waves, may be linked to health problems in people living nearby.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Three of the largest thermo-electric plants in Alberta are located on Lake Wabamun, which is about 70 km west of Edmonton. Keephills, Sundance, and Wabamun plants produce enough electricity to supply the equivalent of 3.3 million Alberta households. More than 15 million t of coal are burned in these three plants each year, all of which are obtained from surface mines in the area. To learn more about the effects they produce on local ecosystems, go to the web site above, and click on Web Links to find out where to go next.

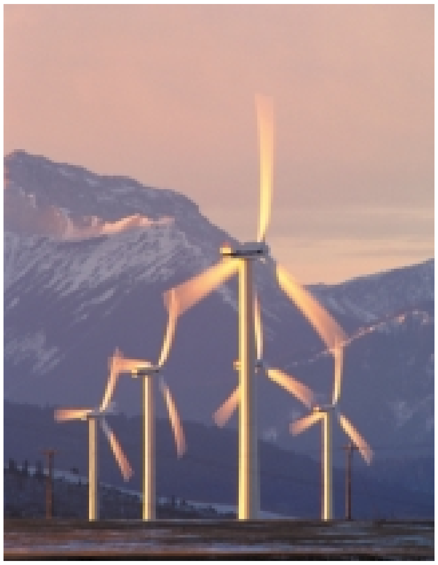


Figure 4.55 Wind turbines similar to these generate electricity which powers C-train public transit equipment in Calgary.

Alternative Energy Sources

In 1998, less than 1% of Canada's electricity was generated from renewable energy sources. As supplies of coal, oil, and natural gas are depleted, however, these fuels are becoming more costly. Energy from the Sun, wind, and tides, which until now has been too expensive or too difficult to harness, is rapidly becoming competitive with conventional energy sources.

Windmills, for example, were used to pump water or generate electricity in rural Alberta for many years. Now, gigantic wind turbines are being used to supply "Green Energy" — electricity generated in an environmentally friendly manner— to the power grid. Large-scale "wind farms" are feasible in regions where the average windspeed exceeds 11 km/h, which is common in southwestern Alberta.

What happens on a windless day? Wind-driven electricity generation must be used together with other electric energy sources or storage devices. For example, wind-generated electricity could charge storage batteries, pump water into a reservoir for generating hydro-electric energy, or split water molecules into hydrogen and oxygen gas for use after as fuel for fuel cells.

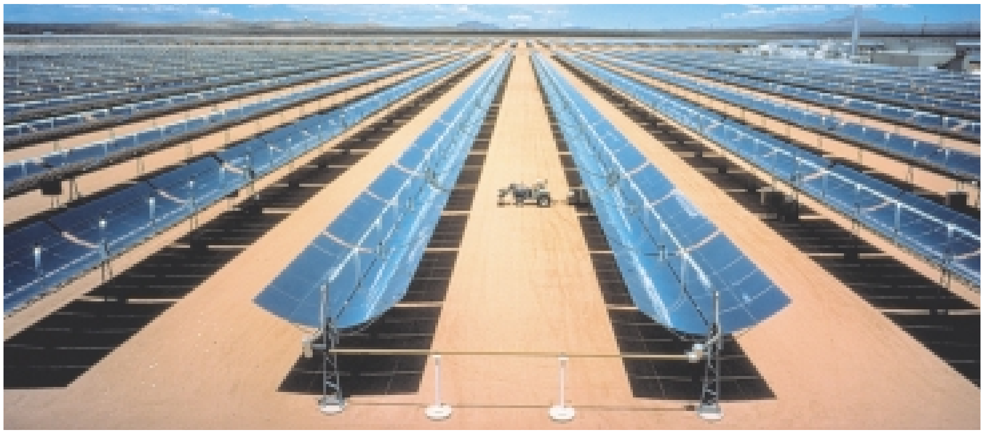
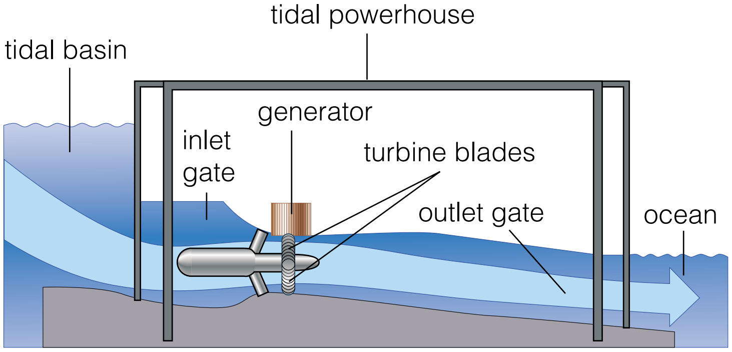


Figure 4.56 Reflective mirrors in the California solar farm are precisely curved to concentrate solar energy on oil-carrying pipes.

Sunlight can also be used to produce electricity on a large scale. "Solar farms" seldom use solar cells because they are expensive, fragile, and convert only about 15% of incoming light energy into electricity. Figure 4.56 shows an alternative method of harnessing solar energy by using it to heat a liquid. The hot liquid flows back to a generating station where it boils water into steam and drives a steam turbine and electric- generator. Solar-energy devices work only when sunlight is reaching the collectors. As a result, solar-powered–generating systems often include storage batteries to supply electricity at night or in cloudy conditions. In sunny conditions, the batteries can be recharged.

Ocean tides are another source of energy that can be used to generate electricity. Twice a day, tides change the water level between 1 m and 17 m, but the enormous energy of this slowly moving water is difficult to utilize. Only a few shorelines around the word have sufficiently high tides and an appropriate shape for trapping tidal waters. Several designs for tidal electricity-generating stations have been tested. As shown in Figure 4.57, the generating station at the Bay of Fundy traps tidal waters that have come in at high tide and uses the energy of the water as it flows out of the bay. Another design allows the station to use the energy of the water continuously, first as it flows into the basin and then again when it flows out of the basin.

Figure 4.57 The tidal powerhouse is quite similar to a hydro-electric generating station in a dam. As the water that has been trapped in the basin flows out, the water pressure turns turbine blades that turn an electric generator.



The hot inner parts of Earth contain a great deal of thermal energy, called **geothermal energy**. In some places, Earth's crust has cracks or thin spots in it. Ground water flows down from the surface, absorbs thermal energy, and rises again as hot springs and geysers. Steam produced by geothermal activity can be used to rotate turbines and turn electric generators. Because heated groundwater may contain dissolved sulfur compounds, condensed steam from the turbines is often pumped back underground to reduce pollution.

Only certain places on Earth have the proper geological characteristics to use geothermal energy. Iceland is one country that is ideally suited for the operation of geothermal power plants. You may remember that Iceland is located on the boundary of two tectonic plates and is known for its volcanic activity. In Canada, other forms of energy are more available and easily accessible, so use of geothermal energy sources has been limited.

Figure 4.58 Geothermal energy may be used in areas such as Iceland. Why isn't this form of energy the answer for other areas on Earth?

Find Out ACTIVITY

Alternative Methods of Generating Electricity

How can we balance our increasing need for electric energy and our concern about environmental problems caused by its production? Which method of generating electricity might help to solve our future energy problems in a practical and environmentally friendly way?

Procedure

1. Choose an alternative form of electrical production or a refinement of a common form of production that interests you.
2. Using the Internet, reference books, or other resource material, collect information about your chosen method of electricity production.
3. Display or present your findings in a format that has been approved by your teacher.

What Did You Find Out? ✷ Analyzing and Interpreting

1. As part of your research, find answers to the following questions.
   - **(a)** What equipment, facility, special conditions, or technology does your method of electricity production require?
   - **(b)** Is this method of electricity production currently being used? Is so, where and by whom? If not, why?
   - **(c)** What impacts, positive or negative, would your method have on the environment?
   - **(d)** What challenges does the development of this method present? (Hint: challenges could be related to such areas as pollution control, energy conversion efficiency, energy transmission, environmental impact, cost/completion, and consumer demand.)

TOPIC 8 Review

1. Describe one environmental concern that can arise for each of the electric power generation methods listed below.
   - (a) hydro-electric
   - (b) nuclear
2. Of the steps involved in producing electric light from coal, which could result in damage to the environment? Explain your choices.
3. For each environment-damaging step mentioned in question 2, describe steps that could be taken to reduce the impact on the environment.
4. Which of the alternative ways of producing electricity would be the easiest and most productive to implement in Alberta? Explain your answer.

Wrap-up TOPICS 6-8

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

electric generator
magnetism
electromagnet
domains
alternating current (AC)
alternators
direct current (DC)
dynamo
power
watt
hydro-electric plants
non-renewable resources
fission products
nuclear fission
thermonuclear
flare gas
rotor
stator
transformers
circuit breakers
fuse
neutral wire
hot wire
ground wire
short circuit
open pit mining
scrubbers
greenhouse gases
thermal pollution
cogeneration
geothermal energy

Reviewing Key Terms

1. In your notebook, match the description in column A with the correct term in column B

A	B
a device that converts mechanical energy into electric energy	power (6)
a generator that produces direct current	dynamo (6)
a metallic conductor with a lower melting point than that of the conducting wires	electric generator (6)
antipollution systems that remove sulfur dioxide from factory smokestacks	stator (6)
energy per unit time	service panel (7)
a two-pole electromagnet in an electric motor	fuse (7)
technology used to “step up” the voltage of an alternating current travelling over long distances	transformers (7)
technology that channels the power entering a home to different circuits	circuit breaker (7)
unwanted heat that is released into the environment	ground wire (7)
uninsulated copper wire	scrubbers (8)
	thermal pollution (8)
	geothermal energy (8)

Understanding Key Concepts

2. Describe the difference between AC and DC. Describe the way(s) in which each form of current electricity is produced. (6)

3. How do hydro-electric plants produce electricity? (6)

4. Describe the function of each of the following electric motor parts. (6)
(a) split ring commutator
(b) armature
(c) brushes

5. Which type of light bulb is more efficient, an incandescent light bulb or a fluorescent light bulb? Explain your answer. (7)

6. In your home, what part of an electricity panel acts as a safety switch that cuts off power if necessary? How does the appropriate component achieve this? (7)

7. What is the process that involves two small atoms coming together to form a larger atom? How could this process be used to produce electricity?(8)

8. What is a kilowatt hour? Provide the formula that would be used to calculate this value. (7)

9. What happens when a “short circuit” occurs? Describe what might cause a short-circuit. (7)

10. Explain what thermal pollution is, how electricity generation might cause it, and why it is a problem. (8)

UNIT 4

Ask an Expert

For the past six years, Su Ling Chong has been involved in a research project at the University of Alberta. Along with a neurophysiologist, mechanical engineer, and system developer, Su Ling works as the medical clinician in a fascinating project that allows people in wheelchairs to use electronic stimulation to propel themselves. This invention means that people who cannot use their leg muscles will have the opportunity to exercise them and stay active.

Q **Have you always been interested in science?**

A Yes. I had great science teachers in schools, and in grade eleven I participated in the Science Olympics and in the Women in Scholarship engineering Science and Technology program (WISEST). As a result, I got the opportunity to participate in an actual research project for six weeks in the summer.

Q **How did you become involved in the wheelchair project at the U of A?**

A As a clinician working with the elderly, I was always very interested in wheelchairs. The community rehabilitation program in which I was working in 1997 was being cut back and I noticed the job posting for a part-time physiotherapist working with electrical stimulation. I got the job. My role in this project is to provide clinical expertise on the wheelchair, determine a subject's suitability to participate, co-ordinate monthly testing and other required appointments, and help analyze the results.

Q **How long has this design been in development?**

A About five or six years. We took all the feedback from our subjects for each of our wheelchair prototypes and continued to improve on it. Biomotion, a medical device manufacturing company, bought the intellectual property from the University of Alberta and has been providing all the prototypes for our research.

Q **Why is this wheelchair unusual?**

A A standard wheelchair allows people to use only their feet on the ground to move along. Paralyzed people are not able to do this at all. They have to use their arms to propel the wheelchair, which may cause overuse injuries in the shoulders. As well, people who have weak leg muscles may not be able to propel effectively with their feet on the floor. This new wheelchair allows people with poor standing balance, weak leg muscles, or an injured spinal cord to drive the wheelchair easily.

Q **How does the wheelchair work?**

A The wheelchair is a standard manual wheelchair with a modified footrest. The footrest is linked to a gear system under the wheelchair, which drives the wheelchair. Users' feet are strapped to the footrest and they propel the wheelchair by bending and straightening their knees. There is a rod on the left side of the wheelchair in the shape of a seven that they can steer with. They can use their hands to help propel the wheelchair when going up ramps. For users who are paralyzed, electrical stimulation is used on their legs to stimulate the muscles that bend and straighten the knees to propel the wheelchair.

Q **How does the electronic stimulator on the wheelchair work?**

A The brain activates muscles in the body by sending electrical impulses to the spinal cord down to the nerve that stimulates the muscles. With spinal cord injuries, the electrical impulses from the brain do not get through, so a person is unable to move his or her legs voluntarily. The custom-made stimulator provides these electrical impulses to the muscles through electrodes placed over the motor points — that's where the nerves are the most superficial in the muscle.

Q **How does this stimulation propel the wheelchair?**

A It can stimulate up to eight muscle groups at the same time or alternately. Once we find all the motor points of the desired muscles for stimulation, we make a cuff to keep the electrodes in place. The user then has only to put on the cuff and the electrodes will be in the right positions. We use three rectangular electrodes on the top of the thigh for the quadriceps muscles and two or three electrodes on the bottom of each thigh for the hamstring muscles. In the "functional" mode, the stimulator is connected to the wheelchair.

Q **How do the muscles know when to react?**

A When the knees are bent in the resting position, the signal of the knee angle is sent to the Bio8 unit from the wheelchair to stimulate the top thigh muscles to straighten the legs. When the quadricep muscles are stimulated, the legs straighten. Once the knees have straightened or reached a threshold level that we have set, the signal is sent to stop the quadricep stimulation and to start the hamstring stimulation to bend the knees. These leg movements drive the wheelchair. The cycle is repeated until the muscles fatigue or the user stops the stimulation.

Q **What does this design mean for people confined to wheelchairs?**

A The implications of this method of propelling are wide. It prevents chronic wear and tear of the shoulder muscles, and it can prevent osteoporosis in the leg bones or increase bone density in the legs. The design helps users maintain muscle tone and muscle bulk and prevent atrophy in the legs while providing good circulation in the legs. It also requires less effort to propel the wheelchair than using the arm-propelled model, and it is easier for users to navigate slopes because they can use both their legs and their hands to propel the wheelchair. Lastly, it's a good cardiovascular workout if the wheelchair is used for long distances.

EXPLORING Further

You have been reading about an electronic wheelchair that enables paraplegics to move their legs. You may also have heard of devices such as electronic pacemakers that help to regulate irregular heartbeats. How do such devices work? What is the connection between electricity inside and outside the body?

How are electrical charges produced and transmitted in the human body? How do they help to keep the human body functioning? Conduct some research into the human nervous system and prepare a report, including diagrams, based on your findings. See if you can find out how positive and negative charges occur in the nervous system.

UNIT 4 PROJECT

My Amazing Electrical Invention

Over the past century, countless electric devices have been invented to meet a wide variety of human needs. As needs change and new technologies are developed, we will have the opportunity to experience many new electric inventions in the future. What would it feel like to be the inventor of a new electric device? How would you go about its development and construction?

Challenge

You will be part of a team that sets out to design and then construct your own amazing electric invention. Your team's invention must be constructed using only the materials approved by your teacher and must meet the Design Specifications listed below.

Materials

Supplied by student teams:

- assorted chemical cells
- electric components from used or discarded toys, electronics equipment, and small appliances (bulbs, LEDs, motors, wire, buzzers, rheostats, etc.)
- materials for invention construction (wood, plastic, cardboard, hinges, pulleys, nails, tacks, screws, glue, etc.)
- tools for construction (hammers, glue guns, pliers, wire cutters, screwdrivers, etc.)

Supplied by the school:

- ammeter
- voltmeter

Depending on supplies at hand, the school may supply:

- D-cells and holders
- cell holders
- copper wire
- Nichrome™ wire
- wire cutters
- bulbs and receptacles

Safety Precautions

- Wear proper eye protection at all times
- Have your list of materials and your plan approved by your teacher before proceeding.

Design Specifications

Your invention must:

A. have a "useful" function that can be easily communicated by your team

B. be self-contained and portable; no size restrictions (within reason) exist

C. be constructed of materials deemed "safe" by your teacher (commercial "electronics kits" may not be used)

D. have electric components installed in one circuit

E. be powered by a DC power source that does not exceed 9V

F. incorporate a minimum of three different types of loads (two bulbs count as one type of load)

G. have at least two separate switches, one of which controls all components while the other(s) control an individual component

H. have a component capable of varying resistance within the circuit

I. function properly in at least two out of three tests

Plan and Construct

1. Brainstorm with your team members to identify a possible function, or functions, for your invention.
2. Draw a prototype blueprint or design diagram that includes proper circuitry symbols for the electrical components. Each team member must contribute a drawing.

3. As a team, choose the design or combination of designs that will best meet your requirements.
4. Present a single labelled diagram of the chosen design to your teacher for approval.
5. Construct your invention.
6. Test, troubleshoot, and evaluate the functionality of your design throughout the construction process.
7. Measure and record the electric current and voltage of your entire circuit, with your "variable resistor" at different settings.
8. Each team member must draw a labelled scientific diagram of the team's invention and a correctly labelled circuit diagram of the electrical components of the device. Note: Be sure to include the symbols for an ammeter and voltmeter at the positions in your circuit where they were connected.

Evaluate

Part A

Invention Evaluation (Shared by All Team Members)

Demonstrate your inventions operation for your teacher, explaining how each design criteria has been met. Based on the construction process your group followed and the performance of your invention, copy and then fill in the following scoring chart.

Part B

Individual Analysis/Understanding of the Circuit Constructed (Individual Mark)

1. Record your team's measured values for current and voltage next to your circuit diagram. Using this data, calculate the resistance within your circuit (show all work and include units).
2. What type of circuit did you construct (series or parallel)? Explain how you know it is this type. Why did your group choose this type of circuit?
3. Describe where your group placed the switches for your device. Explain why they were positioned this way.
4. Which types of energy were produced and used by the various components in your invention? (State energy conversions, e.g., electrical to mechanical.)
5. What type of component did your group use to vary resistance? Why did you install the variable resistor where you did, and how did it affect the operation of your invention?
6. State whether your invention passed the testing procedure. Describe what aspects of the design and/or construction process were least difficult and which were most difficult.

Catagory	Criteria	Score	
		Student Self-Evaluation	Teacher Evaluation
Planning Process	Initial Individual Diagram Final Group Plan	/5 /5	/5 /5
Construction Process	General Preparedness of group/individual Efficient Use of Time by group/individual	/5 /5	/5 /5
Specifications	Inclusion of Required Components Successful Operation	/10 /10	/10 /10
Aesthetics/Appearance	General Apperance Ease of operation (convenience)	/5 /5	/5 /5
	Total Score	/50	/50

UNIT

4 Review

Unit at a Glance

- Excess electrons on an object create a negative charge. A shortage of electrons creates a positive charge.
- The Laws of Charge state that
  (a) unlike charges attract
  (b) like charges repel
  (c) charged objects attract uncharged (neutral) objects
- Conductors allow electric charge to move freely. Insulators prevent charge from moving freely.
- The basic parts of all electric circuits are a source of electric energy, conductors, a load, and a control device.
- Quantity of charge is measured in coulombs.
- Current is measured in amperes.
- Voltage (potential difference) is a measure of the energy of a standard unit of charge, and is measured in volts.
- Resistance is the property of substances that hinders charge motion and converts electric energy in to heat. Resistance is defined as the ratio of voltage to current (Ohm's Law).
- A series circuit has one current path. A parallel circuit has more than one path along which current can flow.
- Thermocouples convert thermal energy to electric energy.
- Piezoelectric materials generate a small voltage when the pressure on them changes.
- Photovoltaic (solar) cells convert light energy to electric energy.
- Alessandro Volta observed that two different metals in a solution could generate a voltage. These observations led to the development of electrochemical cells and batteries, which consist of several cells connected together.
- Electric generators convert mechanical energy to electric energy. Their operation is based on the relationship between magnetism and electricity.
- Direct current (DC) flows in only one direction. Alternating current (AC) reverses direction periodically.
- The power grid generates and distributes AC electricity using transformers to change voltage for efficient power transmission.
- In homes, electric current travels through an electric meter and a service panel to branch circuits. Circuit breakers or fuses in the service panel cut off excessive current before wiring can overheat.
- Electric power is the product of voltage and current. Power measures the quantity of energy transfer each second.
- All electric devices convert some input energy into waste heat, so they are not perfectly efficient.
- Most of Canada's electric energy is generated using dams, thermo-electric plants that burn fossil fuels, and nuclear reactions.
- All methods of producing electricity affect the environment. Renewable sources of electric energy include biomass fuels and solar, wind, tidal, and geothermal energy.

Understanding Key Concepts

1. What does it mean to say a conductor is "grounded"?

2. Describe how positive and negative unbalanced charges are produced.

3. Why must electrostatic buildup in machinery be prevented? Give at least two examples to support your answer.

4. How does resistance within a series circuit change when more bulbs are added. Explain your answer.

5. Explain how piezoelectricity produces electric current.

6. Describe at least three factors that would affect the electrical production of a photovoltaic cell.

7. Which "batteries" used in daily life are actually not batteries? Explain your answer.

8. Describe one advantage and one disadvantage of a hydrogen fuel cell.

9. Draw a labelled diagram of the main parts of a thermo-electric generating station.

10. What is the main function of the stations and sub-stations located along the power grid? Why is this function necessary?

11. Describe the appearance and function of each of the three wires found within a cable commonly used for home wiring.

12. Draw a circuit drawing of a bedroom that contains two lights controlled by a switch, four plug-ins that constantly have power, and a closet with a light and its own switch that runs independently of the rest of the room. (You will need to invent a symbol for the plug-ins.)

13. What is the electrical efficiency of a 100 W light bulb that produces 5.7 kJ (57 000 J) of heat when it is on for 10 min? (Hint: remember that the bulb is supposed to produce light.) Show your work.

14. Why do we need to find alternative methods of producing electricity?

Developing Key Skills

15. Bob charged objects A and B by rubbing them together. Once charged, Bob moved object B close to a third object, object C, and made the following observations. For each observation below, answer the accompanying question.

    (a) Object **B** was attracted to object **C**. If object **B** is known to be negatively charged what is the charge of object **C**?

    (b) Object **C** was also attracted to object **A**. What is the charge of object **C**?

    (c) Based on the observations above, what is the charge of object A?

16. In your notebook, draw a circuit diagram for a circuit containing, two cells, one bulb and one switch.

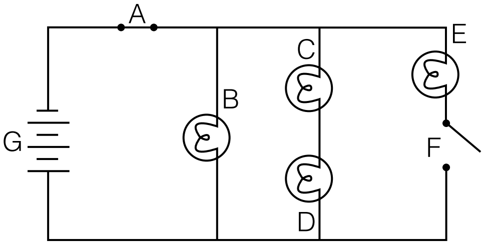
17. Describe at least three conditions that must be met in order for the bulb in the circuit in question 2 to light.

18. **(a)** If the voltage in the circuit drawn for question 2 was 3.0 V and the bulb had a resistance of 24 Ω, how much current would be flowing through the circuit?

    (b) If the number of cells was increased to four, what would the current be?

19. Describe three different ways in which chemical energy could be converted to electricity.

20. Examine the circuit diagram below and then answer the questions that follow.



(a) How many batteries are shown in the circuit above?

(b) Which of the bulbs would presently be on the way the circuit is pictured?

(c) If bulb C were to burn out and switch F was closed, which bulbs would be lit?

(d) In what direction are the electrons flowing in the above diagram? (clockwise or counterclockwise) Explain your answer.

Problem Solving/Applying

21. How many 100 W bulbs would a family have to remove in order to save $25.00 in a 30-day month? The bulbs are on for an average of 6 h per day and electricity costs $0.11 per kWh. (Please show your work.).

22. Glenda wishes to run several metres of speaker wire from the upstairs stereo to her downstairs bedroom. Describe at least three measures Glenda should take to ensure that her bedroom speakers receive the strongest signal possible. Explain each of your suggestions.

23. Shavez works in a factory that constructs highly sensitive computer components. Damage to their product due to electrostatic discharge (ESD) is of great concern to the owners of the company. Describe three different measures that Shavez or the owners could take that would decrease the chances of product damaging ESD.

24. Describe three positive ways in which people make use of electrostatic phenomenon.

25. Why do most power plants produce alternating current rather than direct current?

26. Describe how you could determine whether a string of holiday lights was wired in parallel or series.

27. Describe two advantages of wiring a circuit in parallel and two advantages of wiring a circuit in series.

28. Draw a circuit diagram of a circuit that would allow you to vary the brightness of two bulbs wired in parallel. The circuit should include a two-cell battery and one switch that controls the entire circuit.

29. In a voltaic cell, what is the function of the following components?

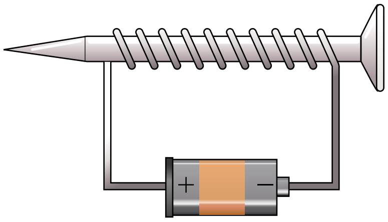
(a) negative electrode (anode)

(b) positive electrode (cathode)

(c) electrolyte

Critical Thinking

30. Use the diagram below to answer the following questions.



(a) Why does the iron nail become a magnet when the battery is connected?

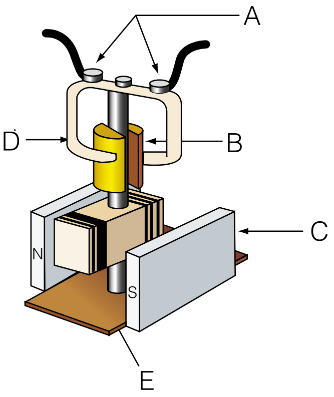
31. Describe the energy conversions that take place in a:

(a) hydro-electric power plant

(b) thermo-electric (fossil fuel) power plant

(c) nuclear power plant

32. Examine the diagram of the St. Louis motor shown below. In your notebook, identify the parts indicated by letters on the diagram. Describe the function of each labelled part.



33. Howard wishes to reduce his electric bill by installing solar cells on the roof of his house. Describe some factors Howard must consider before undertaking this project.

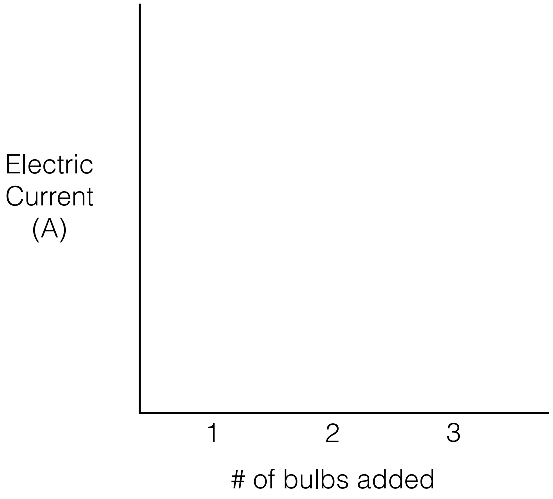
34. Describe three alternative ways of producing electricity that have minimal impact on the environment. Explain the reasons for your choices.

35. Explain why each of the alternative methods for producing electricity that you mentioned in question 35 are not as commonly used as the traditional sources of electricity.

36. What would the power rating (in watts) be for a vacuum cleaner that requires 12 A of current from a 120 V circuit? How many joules of energy would the vacuum use in 10 min of use? (Show your work.)

37. What is the electrical efficiency of an electric water heater (with a power rating of 6300 W) that can raise the temperature of 151 L of water 10°C in 15 min (Hint: it takes 4180 J to raise the temp of 1 L of water 1°C)?

38. What happens to the electric current flowing within a parallel circuit compared to the electric current flowing within a series circuit when more bulbs are added? Illustrate your answer by copying the axis illustrated below into your notebook. Plot a line that represents the series circuit electric current and another that represents the parallel current.



Hint: Include a legend and use a different coloured line to indicate each circuit type.

39. What is the main source of electricity for the province of Alberta? Give reasons why this method is so popular, and identify some of its advantages.

Pause&Reflect

Go back to page 264 at the beginning of this Unit, and check your original answers to the Focussing Questions. How has your thinking changed? How would you answer those questions now that you have investigated the Topics in this Unit?